Science Policy Study—Hearings Volume 4
INTERNATIONAL COOPERATION IN BIG SCIENCE: HIGH ENERGY PHYSICS

HEARING

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

FIRST SESSION

APRIL 25, 1985

[No. 49]

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INTERNATIONAL COOPERATION IN BIG SCIENCE: HIGH ENERGY PHYSICS

THURSDAY, APRIL 25, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to notice, at 9:06 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. Good morning, ladies and gentlemen.

Today's hearing is the first in a series of four Science Policy Task Force hearings on international cooperation in science. The focus of this hearing is international cooperation in big science, as personified by the field of high energy physics.

It has often been asserted that elementary particle physics has a number of features that make it a natural for international collaboration. The problems pursued are of a truly fundamental nature, and the aims are deeply cultural and remote from the interests of economic gain or military use.

These features result in openness of communications among researchers in the field and ease of publication in journals circulated worldwide. Such openness naturally encourages competitiveness on an international scale.

Exploration of the fundamental constituents of matter and the fundamental forces of nature requires the use of large and expensive accelerator complexes. The next generation of high energy physics facilities may well cost several billion dollars each and could be too expensive for a single nation to construct and operate on its own.

Indeed, of particular interest to our task force is the question: What is the past experience and future prospects for international costsharing of the next generation of high energy physics facilities, both in terms of construction and in operation?

Today we have a number of distinguished witnesses who will address this and other issues concerning international cooperation. We will hear of the status and plans of the world's major high energy physics programs and facilities, including the Japanese National Laboratory for High Energy Physics, the German Electron Synchrotron Laboratory, and the European Laboratory for Particle Physics.

Also represented here are the U.S. programs at Fermi National Accelerator Laboratory, the Stanford Linear Accelerator Center, Brookhaven National Laboratory, and Cornell University.

We will also receive testimony concerning current international planning activities, including those of the Summit Working Group on High Energy Physics, the European Committee for Future Accelerators, and the International Committee for Future Accelerators.

Finally, I might note that in addition to our group of distinguished witnesses, we also have a group of distinguished discussants who will offer their perspectives in the questioning period following the formal presentations.

I would yield to Mr. Lujan for any comments that he wishes to make.

Mr. LUJAN. Thank you, Mr. Chairman.

It is indeed a great pleasure to have a panel as distinguished as we have. One of the concerns—and you have mentioned it already—is what do we do about these more expensive machines that we need to carry on this research that requires higher and higher energy all of the time? I would be very interested in the witnesses' views of international cooperative ventures.

So I look forward to this hearing, Mr. Chairman, and I ask unanimous consent to include in the record a statement at this point.

Mr. FUQUA. Without objection, it will be made part of the record.

[The prepared opening statement of Mr. Lugan follows:]

OPENING REMARKS OF HON. MANUEL LUJAN, JR., SCIENCE POLICY TASK FORCE

I first want to join Chairman Fuqua in welcoming our distinguished international guests.

While research in the field of elementary particle physics is a fascinating but highly esoteric subject to us laymen, I know that the members of our task force will have no difficulty in fully appreciating the funding requirements for supporting this research. And as higher and higher energies are required to probe ever deeper into the substructure of the atom, higher and higher appropriations are required to provide the necessary support in facilities, equipment and personnel. Indeed, we are now beginning to look at spending several billion dollars for the next-generation particle accelerator, the Superconducting Super Collider. Without belaboring the point, because it is not my intent to demean the essential nature of this research by only discussing its cost, I think we can all see that the need for international, industrial, regional and State collaboration in constructing and operating such large scientific projects becomes not just desirable but perhaps essential.

Our guests today are uniquely qualified to provide our science study with some invaluable insights into past and future prospects for international collaboration in high energy physics. I look forward to their testimony.

Mr. FUQUA. Let me advise our panelists that in this field of modern-day technology, you have two different types of microphones. One of this type is for the audio in this room; the other smaller microphone is for the reporter so that they can make an accurate transcript of the hearing. So, when you speak, if you will have both close by, and we will have to pass them back and forth to ensure that not only the audio in the room is adequate, but also that it is appropriately carried so that the reporter can record all of it.

We begin with Dr. Ozaki, the chief director of the TRISTAN project at the Japanese National Laboratory for High Energy Physics, and we will be pleased to hear from you at this time.

[A biographical sketch of Dr. Ozaki follows:]

Name: Satoshi Ozaki.
Current address: 746 Takezono 3, Sakura, Niihari, Ibaraki, Japan.
Date and place of birth: July 4, 1929, Osaka, Japan.

EDUCATION

School, location, dates attended, and degree:
MIT, Cambridge, MA 9/55-5/59, Ph.D., physics.
Osaka University, Osaka, Japan, 4/53-8/55, M.S., physics.
Osaka University, Osaka, Japan, 4/49-3/53, B.S., physics.
Academic honors: Fulbright Grant—'55-'57.

MEMBERSHIP IN ORGANIZATIONS

American Physical Society, Physical Society of Japan:
Date and title:
4/83-present—Chief Director, TRISTAN Project, KEK.
1/81-3/83—Director, Physics Dept., KEK.
1/81-present—Professor, National Lab. for High Energy Physics (KEK), Physics Dept.
7/72-9/83—Senior Physicist, Brookhaven National Lab., Physics Department.
6/66-7/72—Physicist, Brookhaven National Lab., Physics Dept.
7/63-6/66—Associate Physicist, National Lab., Physics Dept.
7/61-6/63—Assistant Physicist, National Lab., Physics Dept.
7/59-6/61—Research Associate, National Lab., Physics Dept.
9/56-6/59—Research Assistant, MIT, Physics Dept.

RESEARCH INTERESTS

Study of high energy particle interaction; particle spectroscopy, high energy physics instrumentation.

DR. SATOSHI OZAKI, CHIEF DIRECTOR, TRISTAN PROJECT, JAPANESE NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS [KEK] TSUKUBA SCIENCE CITY, JAPAN

Dr. Ozaki. Honorable chairman, Mr. Fuqua, and members of the committee, it is my great pleasure to be here to present to you the current status of the High Energy Physics Program in Japan, particularly of the National Laboratory for High Energy Physics, which is commonly called KEK, standing for—Japanese phrase—in Japanese.

The director-general of our laboratory, Dr. Nishikawa, regrets that a previous engagement prevents him from being in Washington, DC, at this time. I am the chief director of the TRISTAN project, Satoshi Ozaki, here to make a presentation in his stead.

The high energy physics activity in Japan began only in 1961 with completion of a 1.3 GeV electron synchrotron in the Institute for Nuclear Study in Tokyo University. With this as a staging point, a major step was made toward the active High Energy Physics Program there in 1971 by the establishment of the KEK—that is our laboratory—where the construction of a 12 GeV proton accelerator was authorized by the Government.

This accelerator was completed in 1976, and an experimental high energy physics program made real progress in Japan in the following year, approximately 20 years behind that in the United States.

KEK, by the way, is operated under the direct administration of MONBUSHO, the Ministry of Education, Science and Culture, and is established as an interuniversity research center for high energy physics which provides a major research tool to users from universities and other institutions. It also provides users with support necessary to run the experiment and carry out data analysis and operating costs.

The laboratory is located at the northern part of the Tsukuba Science City and is approximately 70 kilometers due north of Tokyo. Its site measures about 1 kilometer in east-west and about 2 kilometers in north-south. Incidentally, I have provided a pamphlet with a picture in front, and on the front page, I show the entire laboratory site.

The laboratory, since its establishment, has made rapid progress in two directions. While engaging in an active program of high energy physics research with the proton synchrotron, the laboratory on one hand has made a significant step toward an application of accelerators to non-high energy physics research.

For instance, construction of a facility to utilize the 500 MeV pulsed proton beam from a high repetition booster synchrotron for the above-mentioned synchrotron was installed in 1978. The pulsed neutron and the meson beams thus obtained opened a new method of study of condensed matter. Investigation showed that the irradiation of a malignant tumor by an intense proton beam gave many favorable results.

On the other side, an accelerator complex which includes a 400-meter-long electron linear accelerator, which you can see in the picture, and a 2.5 GeV electron storage ring was built which is dedicated for research using synchrotron radiation, and that was commissioned in 1983.

The synchrotron radiation, as is well known, provides an intense pencil beam light with a continuous spectrum ranging from visible to x-ray and is very useful for research in the fields of solid state physics, biophysics, microanalysis, microlithography, and so on. Lately, its importance in new technologies, such as R&D for the super-large scale integrated circuits, study of catalysts, and medical application for the diagnosis of blood circulation, was recognized widely.

In the other direction, KEK is making a strong effort toward reaching an energy frontier in elementary particle interactions in pursuit of an ultimate understanding of matter; this is, high energy physics. This effort is called TRISTAN, which I am directing.

In this project, an electron-positron colliding beam accelerator with a circumference of 3 kilometers is being built. This project began in 1981 as a 5-year project with a total budget of 85 billion yen, which is approximately $340 million, including civil construction, accelerator components and detectors, but excluding salaries. The salary account is separate in Japan.

The total number of staff members at the laboratory is approximately 500 at the moment and is quite small compared to that at comparable European and U.S. laboratories.

However, close cooperation with the leading industries there has made it possible for us to carry out our mission to date, and this

cooperation, so to speak, has been the special characteristic of Japanese accelerator projects. This type of cooperation, by the way, we believe is indispensable for the future super-large-scale accelerator project.

At the same time, we believe that the advancement of the technological frontier and the basic science frontier are in a relationship like that of the chicken and the egg, and both frontiers advance hand in hand. This has been the way our director, Nishikawa, has been thinking all along.

Now, getting back to TRISTAN, with a nominal collision energy of 30 GeV on 30 GeV and anticipated luminosity which is 2×10^{31} cm^{-2} sec^{-1}, this collider will become the world's highest energy electron storage ring when it is completed in late 1986, opening a new energy regime to be explored.

Coupled with this project, intensive research and development of advanced technology related to the accelerator and detector is being carried out by the laboratory in collaboration with industry and also the other laboratories in foreign lands. This includes the work on superconducting magnets, superconducting radio frequency cavities, superhigh vacuum components, and so on.

Taking the spirit of ICFA, the International Committee for Future Accelerators, which stated that a major accelerator in any region be open to the researchers of other nations, we intended to make this TRISTAN collider available to the worldwide community of high energy physicists from the beginning.

As such, we have not only invited the research groups abroad to propose experiments at TRISTAN but also have had one prominent physicist each from the United States and from Europe on our 9-member program advisory committee to evaluate the proposals.

We are happy to note that two of the four experiments at TRISTAN are by international collaboration. Namely, one experiment called AMY is a collaboration of groups from the United States, Japan, China, and Korea. In this case, major support is provided by the first two, namely, the United States and Japan. The other experiment, though it is quite small in scale, is primarily by a team from the United States.

Well, as it is well known, the field of high energy physics is quite international, and scientists visit foreign laboratories for the sake of their research. We are happy to note that the KEK has received in the past 5 years 99 scientists for a variety of stays ranging from 1 month to 4 years for their research.

In addition, Japan has two formal agreements of international cooperation in the field of high energy physics, one of which is by an implementing arrangement signed on November 11, 1979, by the U.S. Department of Energy and MONBUSHO, which is our agency.

This program has annual funding from the Japanese Government of about 1.5 billion yen—which is $6 to $7 million, depending on the exchange rate at the time—for direct support of the experimental program at the U.S. laboratories and accelerator and detector R&D. This program allowed Japanese scientists to cooperate with their U.S. counterparts in the experiments at SLAC, Fermilab, and BNL, and produced many successful results.

In this regard, I wish to express our sincere appreciation for the hospitality given to the Japanese participants by U.S. laboratories and the understanding shown by U.S. science authorities.

The other cooperation is by an agreement between the University of Tokyo and CERN in which Japanese scientists will collaborate in an experimental project for LEP at CERN.

Now, at present, the high energy physics community of Japan is directing its full efforts toward the ongoing program, namely the completion of the TRISTAN project on time, a resumption of the 12 GeV proton synchrotron program, which was shut down for about a year, and the collaboration with the U.S. laboratories and CERN and also with DESY.

The scientists, however, began to discuss the course which the High Energy Physics Program of Japan should take after the TRISTAN Research Program is going, namely in the 1990's and beyond. The discussion is being made by a working group on the long-term planning which was established last year and which is made up of young scientists who are expected to be active in the 1990's.

Needless to say, the working group is considering, as one of the further possibilities, participation by Japanese scientists in the experimental program at the Superconducting Super Collider, which is being discussed here as the future of the United States.

Thank you, gentlemen.

[The prepared statement of Dr. Ozaki follows:]

Prepared Statement of Dr. Ozaki

Honorable chairman, Mr. Fuqua and the members of the committee, it is with my great pleasure to be here to present the current status of the high energy physics program of Japan, particularly of the National Laboratory for High Energy Physics which is commonly called "KEK". The Director-General of our laboratory, Dr. Tetsuji Nishikawa regrets that a previous engagement prevents him from being in Washington DC at this time, and I, Prof. Ozaki, the Chief Director of TRISTAN project on which I shall refer later, am to present this address in his stead.

The high energy physics activity in Japan began only in 1961 with completion of a 1.3 GeV electron synchrotron in the Institute for Nuclear Study in Tokyo University. With this as a staging point, a major step was made toward an active high energy physics program there in 1971 by an establishment of KEK, where the construction of 12 GeV proton synchrotron was authorized by the government. This accelerator was completed in 1976 and an experimental high energy physics program made progress in Japan in the following year, approximately 20 years behind that in the U.S., taking for instance, the 3 GeV proton synchrotron at BNL, COSMOTRON, as the time marker. KEK is operated under a direct administration of MONBUSHO, the Ministry of Education, Science and Culture, and is established as an interuniversity research center for high energy physics which provides a major research tools to users from universities and other institutions. It also provides users with support necessary to run the experiment and carry out data analysis. The laboratory is located at the northern part of the Tsukuba Science City and is approximately 70 kilometer due north of Tokyo. Its site measures about 1 kilometer in east-west and about 2 kilometers in north-south.

The laboratory, since then, has made a rapid further progress in two directions. While engaging in an active program of high energy physics research with the 12 GeV Proton Synchrotron, the laboratory on one hand has made a significant step towards an application of accelerators to non-high energy physics research. For instance, construction of a facility to utilize 500 MeV pulsed proton beam from a high repetition injector synchrotron for the machine mentioned above was initiated in 1978. The pulsed neutron and meson beams thus obtained opened a new method for the studies of condensed matter and etc. An investigation showed that the irradiation of malignant tumors by intense proton beam gave many favorable results. An accelerator complex which includes a 400 meter long electron linear accelerator and a 2.5 GeV electron storage ring, dedicated for a generation of synchrotron radiation

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In the other direction, KEK is making a strong effort towards reaching an energy frontier in elementary particle interactions, in pursuit of an ultimate understanding of the matter, i.e. high energy physics. This effort is called the "TRISTAN" project in which an electron-positron colliding beam accelerator with the circumference of 3 kilometers is being built. This project began in 1981 as a five year project with its total budget of 85 billion yen (340 million dollars) including civil construction, accelerator components and detectors but excluding the staff wages.

The total number of staff members at the laboratory is approximately 500 and is quite small compared to that at comparable European and the U.S. laboratories. However, a close cooperation with leading industries there has made it possible for us to carry out our mission to date, and this cooperation, so to speak, has been the special characteristic of Japanese accelerator projects. This type of cooperation, we believe, is indispensable for a future super large scale accelerator project. At the same time, we believe that an advancement of technological frontier and basic-science frontier are in a relationship like that of chicken and egg, and both frontiers advance hand-in-hand. This has been a philosophy of our Director-General Nishikawa.

With a nominal collision energy of 30 GeV on 30 GeV and anticipated luminosity of $2\times10^{31}cm^{-2}sec^{-1}$, this collider will become the world highest energy electron storage ring when it is completed in late 1986. Coupled with this project, an intensive research and development of advanced technology related to the accelerator and detector is being carried out by the laboratory in collaboration with industries. This includes the work on superconducting magnets, superconducting radio frequency cavities, super-high vacuum components, naming a few.

Taking the spirit of ICFA, International Committee for Future Accelerators, which stated that a major accelerator in any region be open to the researchers of other countries, we intended to make this collider available to the worldwide community of the high energy physicists. As such, we have not only invited research groups abroad to propose an experiment at TRISTAN, but also have had one prominent physicist each from the U.S. and from Europe in our nine-member Program Advisory Committee to evaluate the proposal. We are happy to note that two of four experiments at TRISTAN are by international collaboration. Namely, one experiment called AMY is by a collaboration of groups from the United States, Japan, China and Korea, major support being provided by the first two. The other experiment, though it is quite small compared to the other three, is mainly by a team from the United States.

As it is well known, the field of high energy physics is quite international and scientists visit foreign laboratory for the sake of their research. We are happy to note that KEK has received 99 scientists from foreign lands in the past five years with the period of stay for research ranging from 1 month to 4 years. In addition, Japan has two formal programs of international cooperation in the field of high energy physics. One of which is by an implementing arrangement signed on November 11, 1979 by U.S. Department of Energy and MONBUSHO. This arrangement is under an umbrella agreement between the two governments on a cooperation in research and development of energy related technologies signed by the U.S. President and the Japanese Prime Minister in 1979. This program, with an annual funding from the Japanese government of about 1.5 billion yen (6 to 7 million dollars depending on the exchange rate) for direct support of experimental program at the U.S. laboratories and accelerator and detector R and D program, allowed Japanese scientists to cooperate with their U.S. counterparts in the experiments at SLAC, FNAL and BNL and produced many successful results. In this regard, I wish to express our sincere appreciation for the hospitality given to Japanese participants by U.S. laboratories and understanding shown by U.S. science authorities. The other is by an agreement between the University of Tokyo and CERN in which Japanese scientists will collaborate in the OPAL detector project for LEP at CERN.

At present, the high energy physics community of Japan is directing its full efforts toward the on-going program, i.e. the completion of the TRISTAN project in time, a resumption of the 12 GeV proton synchrotron program and the collaboration with U.S. laboratories. The scientists, however, began to discuss the course the high energy physics program of Japan should take after TRISTAN research program, i.e. in 1990's and beyond. The discussion is being made by a working group on the long

term planning which was established last summer, and made up of young scientists who are expected to remain active in late 1990's. Needless to say, the working group is considering as one of the further possibilities a participation by Japanese scientists in the experimental program at the Superconducting Super Collider, which is being discussed here as the future program for the United States.

Thank you.

Mr. FUQUA. Thank you very much.

Before we have our next presenter, I would like to recognize two very distinguished people in our audience. First is Prof. Sam Ting, who shared the Nobel prize with one of our later discussants, Dr. Richter of SLAC. Also, we have the former director of the National Science Foundation and a very fine scientist himself, Dr. Ed Knapp. Dr. Knapp, we are glad to have both of you here today.

Our next presenter will be Professor Soergel from the German Electron Synchrotron Laboratory, DESY, in Hamburg, in the Federal Republic of Germany. Dr. Soergel, we are very glad to welcome you here.

I might say, too, that we will make the statements part of the record. If you wish to summarize, if that takes less time—if it takes more time to summarize, then we would prefer that you stick with the prepared remarks. [Laughter.]

STATEMENT OF PROF. VOLKER SOERGEL, DIRECTOR, GERMAN ELECTRON SYNCHROTRON LABORATORY [DESY] HAMBURG, FEDERAL REPUBLIC OF GERMANY

Professor SOERGEL. I would like to summarize but using the Vu-Graph. Is this possible?

Mr. FUQUA. Yes, fine. That would be great.

Professor SOERGEL. It may save some time.

Mr. Chairman, Representatives, ladies and gentlemen, I am honored and pleased that I can take part in this discussion today on the future of high energy physics. I have been asked to give a brief statement about the present status and the plans of the German Laboratory for High Energy Physics, Deutsches Elektronen Synchrotron, DESY, in Hamburg.

DESY is a laboratory for basic research. It has two areas of research, high energy physics and synchrotron radiation. The facilities of the laboratory are two large, e^+e^- storage rings, DORIS and PETRA, which are used to do high energy physics experiments. DORIS is also used as a synchrotron radiation light source.

So our installations are very similar to the installations, for instance, at SLAC or at Cornell, and we have quite a related research program and very good relations with the two laboratories.

Slide 1

The lab is situated in Hamburg city, and you see here on this slide the present DESY site in the midst of a large city. I think it is unique to have a laboratory of this size in a city, since the PETRA storage ring is 2.3 kilometers across.

DESY

Areas of research: High energy physics
Synchrotron radiation

Facilities:
- e^+e^- storage rings
  - DORIS 2×5.4 GeV, Argus, crystal ball, 2D
  - PETRA 2×23 GeV, Tasso, Mark J, Jade, CELLO 4D
- Synchrotron radiation lab HASYLAB (DORIS)

Future project: ep collider HERA
$E_e = 30$ GeV, $E_p = 820$ GeV

DESY staff ~ 1000

Scientists doing research here

High energy physics		470
DESY staff	60	
German Univ. + research lab	140	
Foreign institutes 16 countries	270	
Synchrotron Radiation mainly German universities.		300–400

Funding: German federal government 90%
State of Hamburg 10%

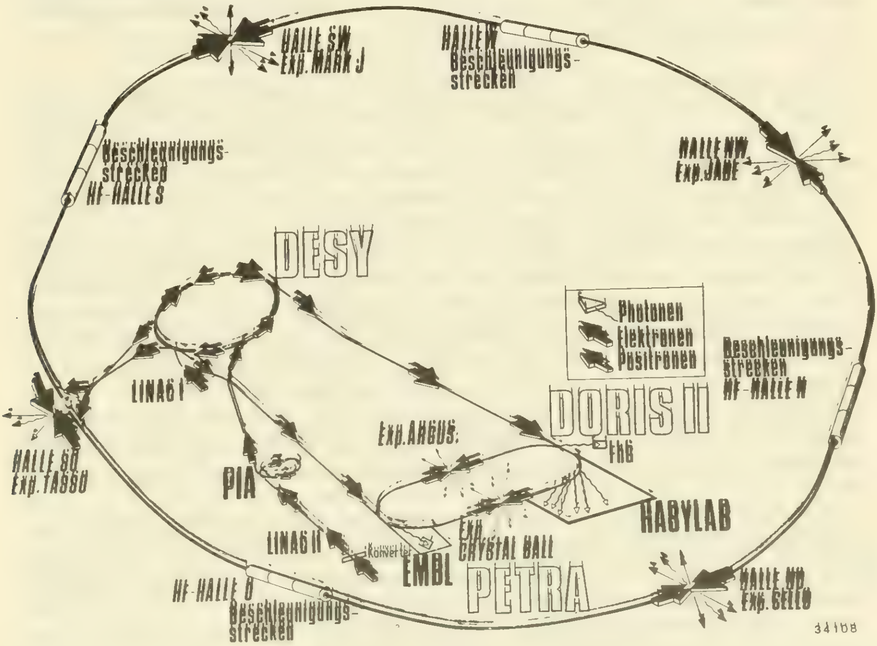
Budget 1985 237 Mio DM
(includes 99 Mio for HERA constr.)

SLIDE 2

To give a little more information about the lab, the staff of the laboratory is about 1,000 people. The number of people doing real high energy research is 470. You see here that most of the people doing research at DESY are coming from outside. We have 60

DESY staff only under that group. We have 140 people from German universities, and then the majority are foreign physicists, 270, which come from 16 countries, among them the United States, in several of our large collaborations.

I can show you in the next transparency the layout of the DESY accelerators. This last ring here is the PETRA storage ring. At the moment, it is an e^+e^- machine with the highest energy in the world until TRISTAN comes into operation. The small one is the DORIS storage ring.



SLIDE 3

Here I show the places where we enjoy the participation of U.S. scientists, so you see that in most of the collaborations, we have U.S. participants. In the Mark J collaboration, Professor Ting is the spokesman of the collaboration.

The high energy physics program in these two storage rings is carried out with full international collaboration. All six stations are operated and have been constructed by international teams in such a way that the various groups have participated through equipment which was brought to DESY—constructed at the home institution, then brought to DESY—put together to make a complete detector, and is now operated together.

So there is no cash flow. I think this is an important element. There is no cash flow. The storage ring facility has been constructed with German funds, and the operational costs for the storage ring facility again come from German funds. It is fully given by the laboratory. The outside contribution comes through the detectors.

Besides the high energy groups, we have the synchrotron radiation users, which are quite a large number, and we are talking about this today.

Let me, as a last remark of the general introduction, say that the funding of the laboratory comes from the German Federal Government, 90 percent, and from the Hamburg State, 10 percent. This ratio is the usual ratio between the local state and the Federal Government for the large research centers in Germany.

This year's budget is 237 million marks, which includes 99 million marks for our future facility, HERA. I should in passing say that Germany, besides the national laboratory in DESY, supports the international laboratory in CERN and shares 25 percent of the cost.

The present program at DESY aims at exploiting the facility storage in PETRA. Our future plans are to construct a new large project which is the ep collider HERA, a large accelerator complex which enables us to collide electrons with protons. It is quite a novel facility which presently does not exist that has two storage rings with two different kinds of particles.

This machine will be built on the same site. It is housed in an underground tunnel of 6-kilometer circumference, so it is a machine similar in size to the Fermilab accelerator, all underground. Again, I would like to point out that the big accelerator, in the midst of a large city and the four experimental stations are placed in locations where there are no houses so they can be built.

Here our construction has begun on this site, on this location here, and the tunneling is started now. We hope to accomplish the completion of this machine by 1989 so the experiments can start in 1990.

The HERA machine needs superconducting magnets to reach its goal for the proton ring, so we will use the technology which has been pioneered at Fermilab and where very important developments also have taken place at Brookhaven.

We enjoy here the strong collaboration of the two laboratories. The design of our magnet was greatly influenced by the work of Fermilab and Brookhaven, and we have now strong contact with both laboratories to get great help, and I would acknowledge this help to our lab in this place. It is very important to us.

The HERA machine will be built with international collaboration, and I will talk a little bit about that because it is a subject of today's meeting. Although international collaboration has been rather strong in the building of detectors, I think it is novel to build an accelerator in international collaboration.

We have been asked by our Government to find international collaborators to help us build the machine and so reduce the costs to be borne by the German Government. We have found a way which is modeled on the collaboration in experiments where the partners contribute not cash money but contribute components of the accelerator or manpower.

We have found nine countries which work with us. In the United States, it is Brookhaven National Lab, which will make available to us some expertise and some installation assistance which helps us to build the machine. I am glad to say that this collaboration

works already very well. I hope very much that this kind of collaboration can expand in the future.

Already in the discussion we had with Brookhaven Lab, it turns out that we have at DESY some installations which can be of mutual benefit to Brookhaven Lab, so we will get a good collaboration in this respect.

I hope that these brief remarks, together with my written statement, give you some impression about the DESY laboratory in Germany.

Thank you.

[The prepared statement of Professor Soergel follows:]

Prepared Statement of V. Soergel, Chairman, DESY Directorate

I am honored and pleased to be able to introduce you today to the program of the Deutsches Elektronen Synchrotron, DESY and to take part in your discussion on the future of high energy physics.

Let me begin with a brief description of DESY and its present activities.

DESY is a laboratory for basic research. It is located in Hamburg (Germany). Its main activity is in the field of high energy physics, a second line of research with growing importance is the utilization of synchrotron radiation in the Hamburg Synchrotron Radiation Laboratory (Hasylab), which is a part of DESY.

The main research facilities of DESY are the electron-positron storage rings DORIS, reaching an energy of 2 x 5.4 GeV, and PETRA, reaching 2 x 23.4 GeV, the highest energy so far obtained in electron-positron collisions.

Six large detectors are installed at the storage rings, two at DORIS and four at PETRA, to study electron-positron collisions. The research program on all the detectors is carried out by international collaborations, involving approximately 470 physicists from 17 countries. In five of these collaborations, we enjoy the participation of scientists from the United States. The two with major U.S. participation, Mark J at PETRA and Crystal ball at DORIS, have U.S. physicists as spokesmen: Prof. Ting from MIT and Prof. Bloom from SLAC.

The synchrotron radiation laboratory at DORIS serves 300–400 users, doing research at 26 experimental stations. They come mainly from German universities and research institutions with, however, also a sizeable participation from abroad.

DESY is funded jointly by the German Federal government (90%) and by the State of Hamburg (10%). DESY has a staff of approximately 1000 people. The DESY budget in 1985 totals 237 Mio DM, including 99 Mio DM for the construction of the new facility HERA. When quoting these figures, it should be remembered that Germany, besides having DESY as a national laboratory for high energy physics, is also a member of CERN and contributes 25% of the CERN budget.

Most of the scientists doing research at DESY are visitors coming from universities and outside research institutes. Here are the present numbers for the high energy physics experiments: About 470 physicists, from which 140 come from German Universities and Institutes, 270 from foreign countries, and only 60 are DESY staff.

THE ONGOING PROGRAM

Aims at the exploitation of DORIS and PETRA:

PETRA will be phased out as a high energy physics facility by the end of 1986 and later be used as part of the injection scheme for the new facility, HERA.

The high energy physics program at DORIS is expected to continue for a few more years. DORIS is now used jointly by the high energy physicists and the users of Synchrotron radiation. There are plans to transform DORIS into a dedicated synchrotron light source as soon as the high energy program comes to an end.

FUTURE PROGRAM: HERA

DESY is now constructing a large new accelerator facility, HERA. This is an electron-protron collider, consisting of two storage rings, one for electrons with an energy of 30 GeV, one for protrons of 820 GeV. Electrons and protrons are made to collide at four intersection points. The two rings will be mounted in an underground ring tunnel of 6.3 km length. The protron ring will be constructed with superconducting magnets.

Construction of HERA began in May 1984, shortly after project authorization was given on April 6, 1984. The facility is planned to be completed in the year 1989, so that the experiments on ep collision can begin in 1990.

The main reasons to choose an ep-collidor as DESY's next project are: The great scientific interest in ep-collisions at very high energies, much higher than available with present accelerators; and the intention to have also in the future a unique scientific program, complementary to the program of CERN and of the other high energy physics laboratories around the world.

HERA will be constructed in international collaboration, with contributions of laboratories and research organizations in several countries. The contributions are either components of the machine developed and built in the participating country, or manpower, by technical and scientific staff sent to Hamburg to collaborate in the construction of the machine. The collaboration involves at present 9 countries including the United States where BNL is our partner.

HERA will be open to physicists from all over the world. The collaboration in the experiments is foreseen in a similar way as practiced now at PETRA and DORIS and—in fact—in most of the high energy physics laboratories around the world.

The main task of DESY in the coming five years will be the construction of HERA and, from 1990 onward, the exploitation of this unique facility in international collaboration.

INTERNATIONAL COLLABORATION AT DESY

As international collaboration is a central issue of your discussion today, I will conclude with a few remarks about international collaboration at DESY.

The figures I have given before show that the majority of the physicists in high energy experiments at DESY come from foreign countries.

In the collaboration on experiments, the various partners contribute components to the detector and so build the detectors jointly. As these detectors are major facilities by themselves, technically demanding and costly, this kind of collaboration has as an important element the cost sharing between the different partners.

DESY provides the operation of the accelerator free of charge, the running costs of the storage rings are paid from the DESY budget.

This way of handling the question of accelerator running costs follows the recommendation of ICFA and is generally accepted by all high energy laboratories. It was an essential element for the development of the strong and very fruitful international collaboration in high energy physics.

The benefit of this international collaboration goes, however, far beyond these budgetary aspects—a point which cannot be covered in this brief introduction.

I hope in conclusion, that with this short introduction I could give you some impressions about the DESY-laboratory and its role in the world wide effort in particle physics research—now and in the future.

Mr. FUQUA. Thank you very much.

The next presenter will be Dr. Brianti, Technical Director of the European Laboratory for Particle Physics in CERN. We are very delighted to have you.

[A biographical sketch of Dr. Giorgio Brianti follows:]

DR. GIORGIO BRIANTI

Born on 14 April 1930 in Parma, Italy.

May 1954—Obtained Degree in Electrical Industrial Engineering, University of Bologna.

September 1954—Joined CERN as a staff member in the Magnet Group of the PS. Until 1958 took part in the design and contruction of the PS Magnet.

1958—Became Leader of the Controls Section in the PS Electrical Engineering Group.

1960—On the creation of the MPS Division appointed Leader of the Controls Group.

1964—Appointed Leader of the MSC Division; directed the work for improving the accelerator and realized the underground external beam for the ISOLDE Project.

1967—Appointed Leader of the newly created SI Division, with the task of designing and constructing the 4-ring 800 MeV Booster Synchrotron as a high-intensity injector for the PS.

1973—Appointed Head of the Experimental Areas Group for the SPS Machine in Laboratory II.

1976—Transferred to the SPS Division, as Head of the Experimental Areas Group.
1977—Appointed Deputy Division Leader of the SPS Division with special responsibility for Experimental Areas.
1978—Reappointed Deputy Division Leader of the SPS Division with Special responsibility for Administrative Matters and Experimental Areas.
1978—Appointed Division Leader of the SPS Division.
1981—Technical Director.

STATEMENT OF DR. GIORGIO BRIANTI, TECHNICAL DIRECTOR, EUROPEAN LABORATORY FOR PARTICLE PHYSICS [CERN], GENEVA, SWITZERLAND

Dr. BRIANTI. Mr. Chairman, Representatives, ladies and gentleman, it is my turn to say that I am honored to be here today, and I convey to you the best greetings and wishes for your work by our director-general, Professor Schopper.

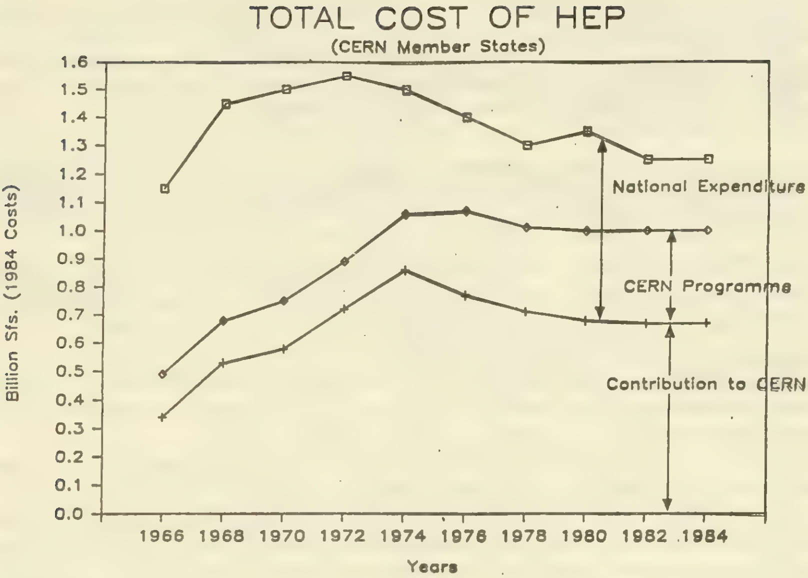
I am going to present to you for a few minutes CERN, the European Laboratory for Particle Physics. CERN is an international organization with, at present, 13 member states, and a 14th one knocking at the door. These member states pay contributions proportional to their gross national product.

CERN was born 30 years ago, almost 31 years ago, and it was born of two basic ideas: the first, to construct collectively in Europe forefront facilities that a single nation could not afford, but also, there was an idea behind it, namely to make Europeans, who had just stopped fighting each other during the war, work together on a day-to-day basis.

Over 30 years of existence, what happened was that the work with protons was concentrated at the CERN international facility, while work with electrons developed at DESY. In those places, very good use was made of existing facilities, the machine of the past being used as the injector into the new, elaborate machine.

We believe that one of the successes of CERN is due to two basic, simple rules: appointment of people on the basis of competence without any quota for nationalities; and contracts for acquiring equipment are placed with the lowest bidder, again without any quota for nationalities.

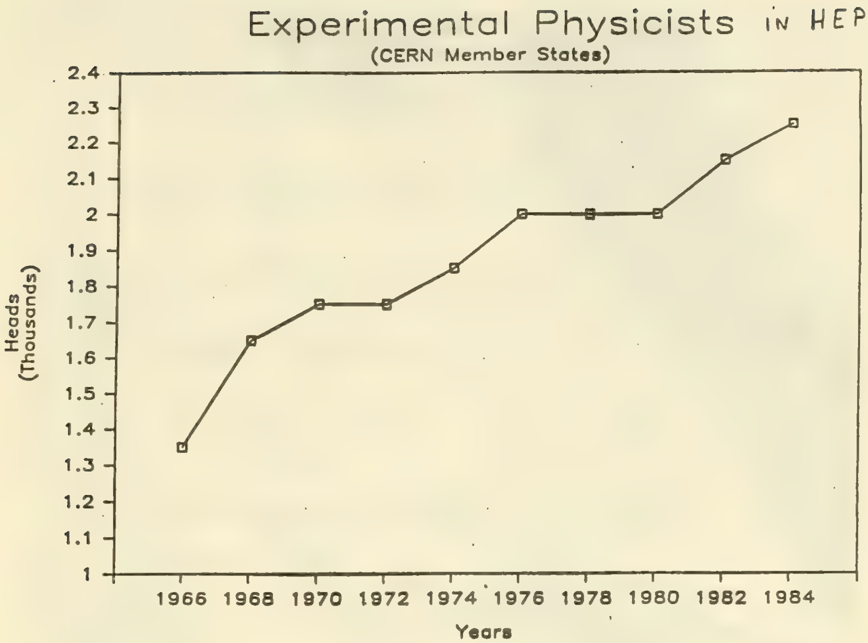
Now, if you will allow me, Mr. Chairman, I would like to show a few slides.



SLIDE 1

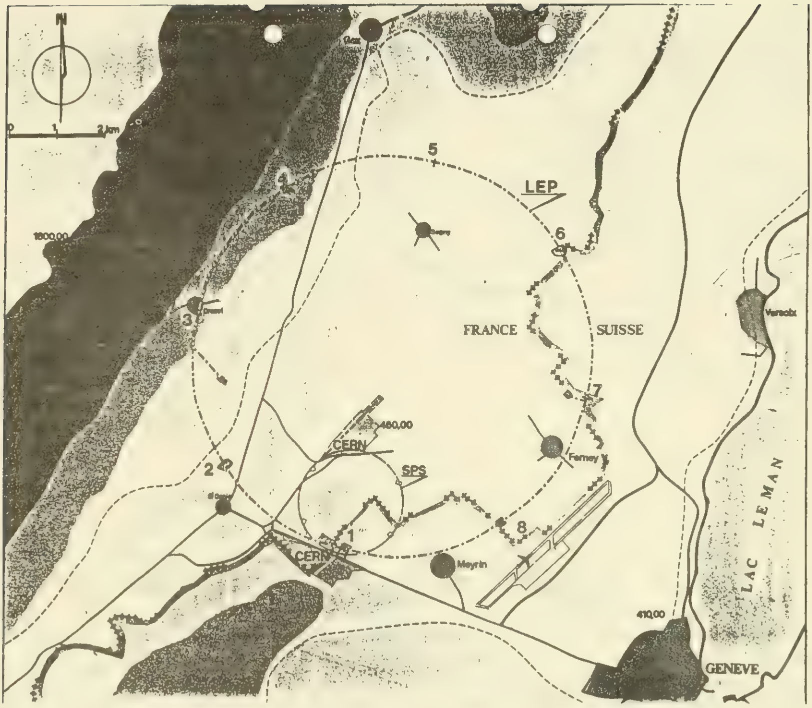
What I show here is the total cost of high energy physics in Europe in billions of Swiss francs. For U.S. dollars, you divide roughly by 2.5 or 2.6. As a function of time, we reached the peak during the construction of the present running facilities, and then there was a decrease and a leveling off.

You see the first component is the contribution to CERN. The second is the contribution nationally but on the CERN Program, and the third is pure national spending. You see that this is leveling off here.



SLIDE 2

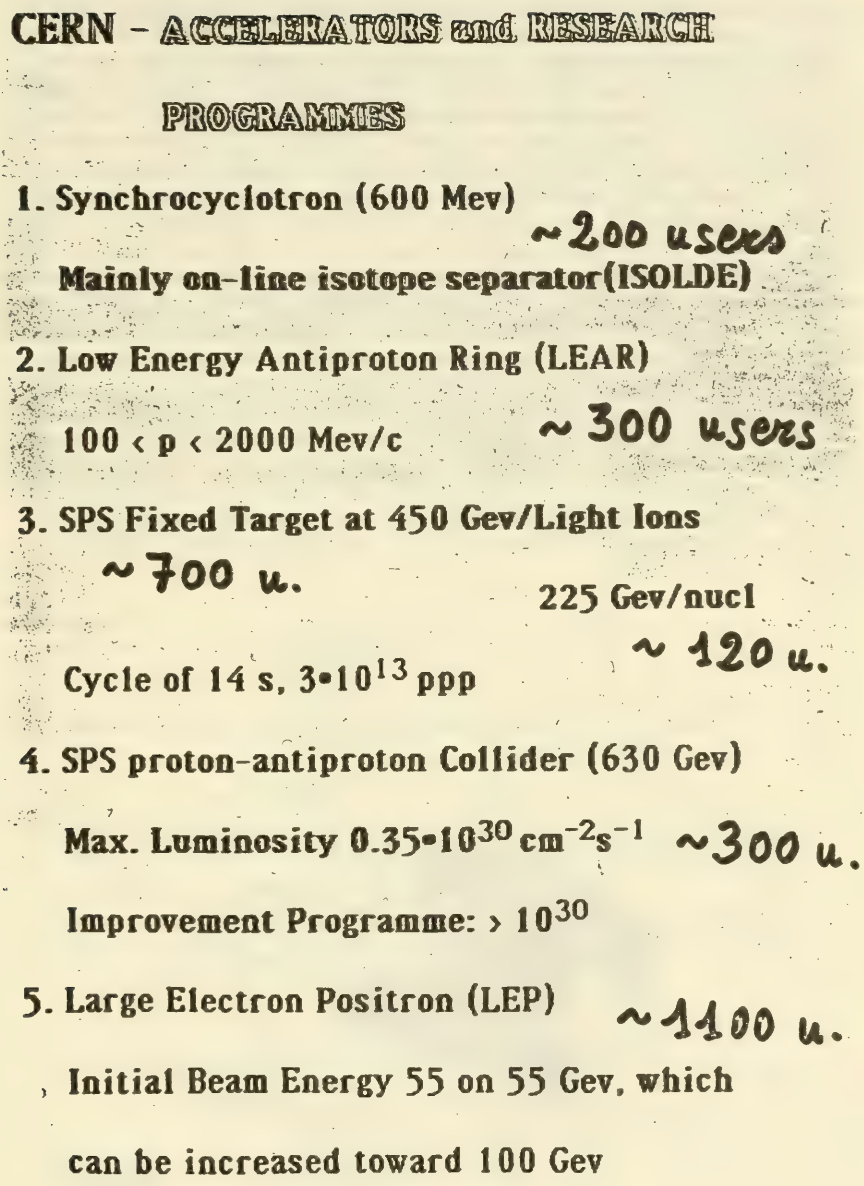
At the same time, the number of users increased. These are experimental physicists in thousands coming from member states. In addition, at the present time, we have about 500 users coming from nonmember states, among those, I believe, a couple of hundred Americans.



SLIDE 3

This is a presentation of the site. You will recognize here Geneva town, Geneva lake, the international airport. It gives you the scale. This is about 5 kilometers.

The present CERN is divided in two sites, one which is called the Swiss site, actually across the border between France and Switzerland, and the other purely in France. The main facility being exploited now is a 7-kilometer proton machine. I will say a few words more in a moment.



Slide 4

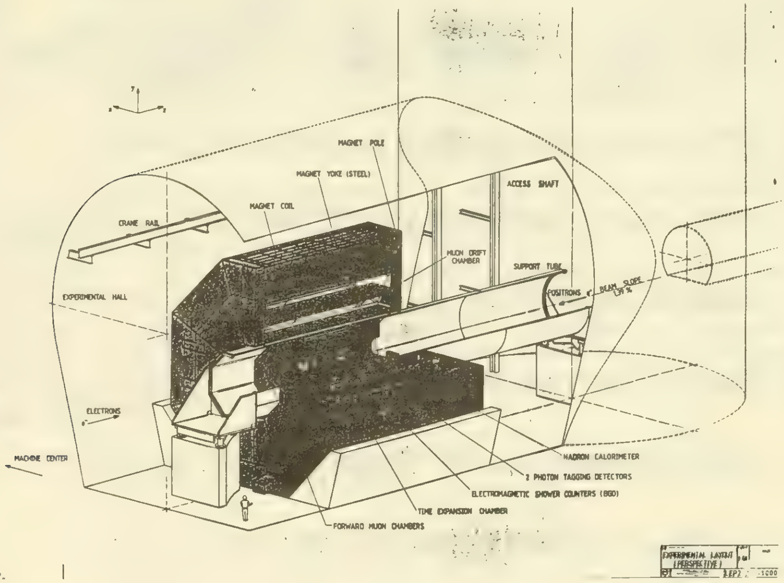
What are our programs? I will list here our programs. The first two are lower energy installations, but still with a substantial number of users. The main running program is centered around the SPS, a facility which provides a fixed target up to 450 GeV, and in the nondistant future, also light ions,

with collaboration involving Lawrence Berkeley Laboratory, which is building an injector for that.

The SPS can also be used as a proton-antiproton collider up to a center of mass energy of 630 GeV. This machine allowed the discovery of the intermediate vector bosons and allowed Professor Rubbia and Dr. Simon van der Meer to obtain the Nobel Prize in physics last year. Let me underline that we are, of course, very glad for this, and in particular because one of the two is an engineer who developed technology which allowed this discovery to be made.

We have an improvement program in order to increase the luminosity. Construction-wise, our largest program now is the construction of LEP. These are electron-positron storage rings of 27-kilometer circumference, which are being dug deep under the soil at an approximate depth of about 100 meters in a tunnel.

This machine will provide, in the first operation, 55 GeV on 55 GeV, but when energy can be developed, up to around 100 GeV per beam. That is what the machine will look like when it is installed. At the moment, this is a wooden model, but we are obtaining pieces. We have placed two-thirds of the industrial contracts, and the tunnel is being dug. The total cost of the machine is $500 million.



SLIDE 5

It will serve four experiments. I will just quickly pass one after the other. This is L3. There is a strong American participation by Professor Ting and cooperators.

There are three others which are all built through international cooperation. Three-quarters of the equipment is built and bought nationally or by institutions. There is only 20 percent CERN par-

ticipation. These are large installations, each one of them involving hundreds of physicists.

The energy of LEP can be developed by using a superconducting cavity, an accelerating cavity which has the great feature to save quite a bit of electric power and to allow us to reach higher energy in an elegant way. The ultimate energy which can be reached depends on the exact state of technology and which field can be obtained and would be in the range of 100 GeV per beam.

What next? Of course, at the moment, we are heavily engaged in the realization of this construction which will end by the year 1988 and will start to be exploited in 1990. However, we are a big laboratory. We have to worry about the future. So our council recently decided to set up a working group to look into the scientific and technological future of CERN and entrusted the chairmanship to Prof. Carlo Rubbia.

This group is to explore the various assumptions which are offered by the existence of the lab tunnel and maybe some other ideas and present a final report in 2 years' time.

LONG TERM OPTIONS for

SECOND MACHINE in LEP

1. ONE-CHANNEL COLLIDER

$p\bar{p}$ E_{cm}= 10 to 18 Tev; L= 10^{31}–10^{32} $cm^{-2}s^{-1}$

ep E_{cm}= 1.2 to 1.8 Tev; L= 10^{31}–10^{32} " "

2. TWO-CHANNEL COLLIDER

pp E_{cm}= 10 to 18 Tev; L= 10^{33} $cm^{-2}s^{-1}$

ep (as for one-channel collider)

INSTALLATION & EQUIPMENT

EXISTING ON CERN SITE (prior to LHC)

1. Excellent Proton Injectors (PS & SPS)
2. Antiproton Source (AA+ACOL)
3. LEP Tunnel and Infrastructure

Slide 6

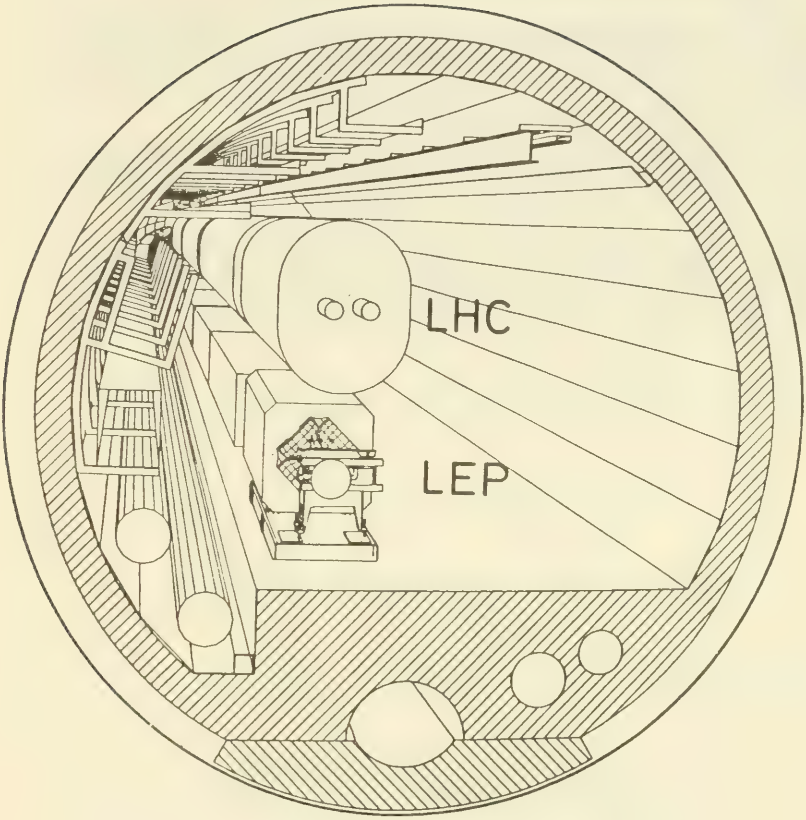
What are the possibilities? The technical possibilities are to put a second machine in the LEP tunnel. There is space enough for that. This would make use of the existing injectors, of the antiproton source if need be, of the LEP tunnel and infrastructure, which accounts for about 50 percent of the total cost of LEP, and also of the electron beam.

And so one can have, depending on the technical solution chosen, a pp-collider with energy up to 18 TeV in the center of mass if superconducting technology can be developed, or at least 10 TeV with present-day technology, and also pp-collisions.

This is a picture of the prospective view of the tunnel, where at the bottom you have the present machine, LEP, and there is space enough on top to add the superconducting collider.

If I have still 1 minute or 2 minutes, it may be of interest to this committee to know that recently we have repeated at CERN a study on the utility of CERN contracts to industry. The first one of these was done 10 years ago, and this has been repeated recently.

DIR-TECH/84-01
May 1984



LARGE HADRON COLLIDER IN THE LEP TUNNEL

A feasibility study of possible options

by

The CERN Machine Group

Slide 7

What has been done is that hundreds of firms who had supplied components to CERN were asked whether the CERN contract provided any additional utility beyond the fact of obtaining that contract. This works this way. I take CERN as an illustration of the field—this is true, I think, in all countries active in the field. If CERN purchases stimulate new products, R&D, improvements on the production technique, quality—it is hard competition, or I said before; the lowest tender wins—all of this may produce additional utility.

Table I: Breakdown of Sample Data (160 firms) by Industrial Category

	Electronics, Optics, Computers	Electrical equipment	Vacuum, Cryogenics, Superconductivity	Steel and Welding	Precision mechanics	Totals
Net utility (MSF)	1576	877	355	225	74	3107
Corrected utility* (MSF)	1340	745	300	190	65	2640
Losses (MSF)	3.7	5.4	5.3	0.4	0.2	15.0
Sales investigated (MSF)	220.1	359.2	101.3	35.8	31.2	747.6
Corrected utility/sales ratio	6.1	2.1	3.0	5.3	2.1	3.5
Number of firms interviewed	57	46	22	16	19	160
Number of firms without utility	12	19	8	8	8	55

* Corrected utility equals 85% of net utility, for explanation see Section V.2.

Slide 8

An external person to CERN has made these interviews of firms, and the utility factor, depending on the field—electronics, electrical equipment, vacuum and so on—ranges, for instance, from 6.1—here, namely, any franc or any dollar that CERN has placed into that firm has further good use, a multiplication factor, because they could sell other products, better products, of 6 or 2 or 3, et cetera. In other words, it is about 4.

It strongly depends on the type of industry, so the most prominent are electronics and informatics in which you have here in white the CERN contract and the utility resulting from that to the firm; less in electrical and steel; less in others.

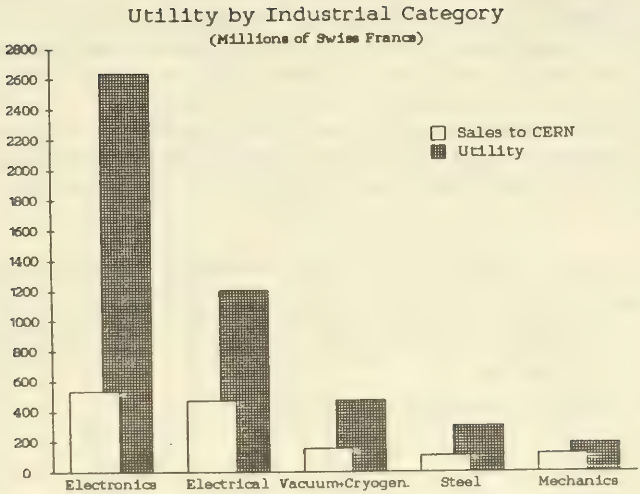


Figure 4: Total sales and total utilities from 519 high technology suppliers, broken down by industrial category.

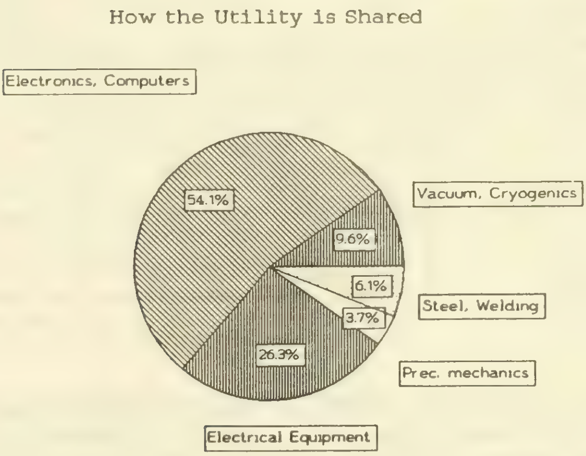


Figure 5: Total utility from 519 high technology suppliers, showing the contribution by industrial category.

SLIDE 9

So in the pie diagram you see that more than 50 percent is in electronics and informatics, but it is an important asset, although, of course, it is not the justification of the field. The present justification is research, but it has this other component.

Let me finish by saying that in addition to the cooperation on experiments, which is really done internationally with a strong participation on many of the experiments all across the world, we have also quite strong collaboration in designs and construction of equipment for accelerators.

I have here a long list, and I don't propose to go through it, but the most prominent one at the moment is a collaboration with Fermilab which is building an antiproton installation as we have pioneered at CERN, and this works in both ways. They are providing test equipment to us; we help them in certain other things. There are very strong collaborations with the SSC Central Design Group in the sense of participation of our accelerator people through workshops and discussion.

Perhaps we could come back on the future during the roundtable discussion, but for the moment, I will stop here, Mr. Chairman. Thank you very much.

[The prepared statement of Dr. Brianti follows:]

Prepared Statement of Dr. Giorgio Brianti, Technical Director, CERN, 1211 Geneva 23, Switzerland

I am honoured to appear before you to-day to supply information about CERN, the European Laboratory for particle physics.

It was founded 30 years ago with two main aims :

i) to pool the resources of 13 Western European States for building fore-front facilities that single countries could not afford,

ii) to let European scientists work together in a strong multi-national collaboration.

Progressively, in the course of the Laboratory's existence the Member States, which contribute to the budget in proportion to their Gross National Product, founded advantageous to concentrate proton accelerators at CERN and to close down all national faciliies. Electron accelerators developed at DESY.

More recently, the construction of the world's largest electron-positron collider (LEP) was decided at CERN, while DESY is developing the only electron-proton collider at the present time.

At CERN, very good use is made of existing facilities, the machines used for physics in the past becoming injectors into the new larger machines.

From the administrative point of view, two simple rules govern the operation of CERN : staff is appointed according to competence, disregarding nationality, and industrial supplies are acquired from the lowest bidder without any quota for the various Member States.

A summary of the activities and prospects for the Laboratory is given in the tables and pictures which I am going to show now.

Fig. 1 gives the total spending fo the Member States according to national expenditures and contribution to CERN.

Fig. 2 gives the number of users from the Member States to which one has to add ~ 500 from non-Member States (~ 200 Americans).

Fig. 3 gives the CERN Accelerator and Research Programmes. The most prominent running programme is the proton-antiproton SPS collider, which led to the discovery of the intermediate vector bosons W and Z (Nobel Prized winners C. Rubbia and S. van der Meer). The largest construction under way is LEP, an electro-positron storage ring, which will operate initially at a centre-of-mass energy of 110 GeV to be increased later on to ~ 200 GeV by adding superconducting radio-frequency cavities.

Fig. 4 gives the layout of the laboratory with dotted lines for the 27 km underground tunnel of LEP, under construction at present. The LEP machine should start operation at the end of 1988.

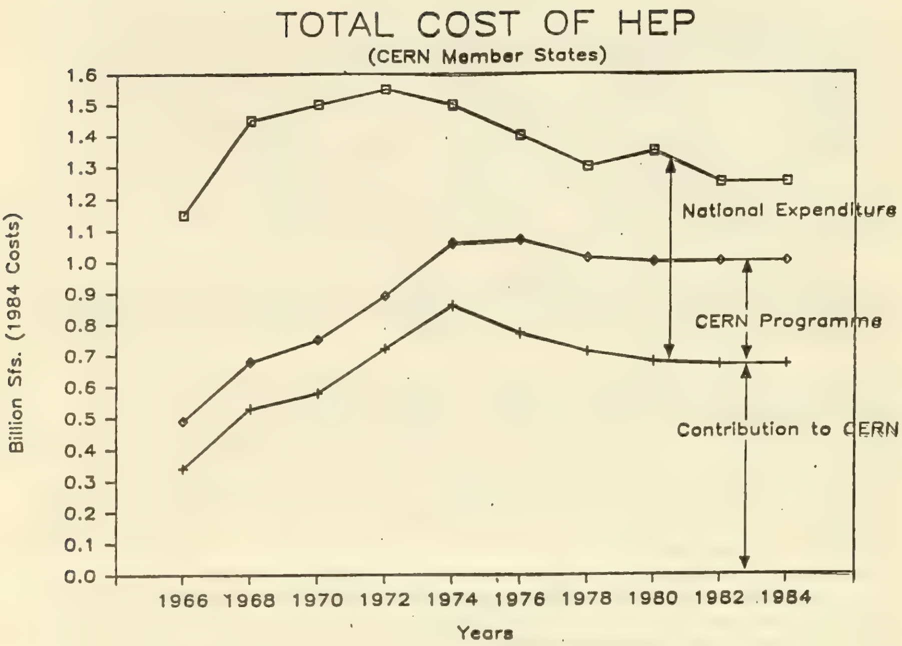
Four large dectectors (Figs. 5, 6, 7 and 8), L3 with important American participation (Leader Prof. S. Ting, MIT), ALEPH, DELPHI and OPAL are in preparation for the LEP programme.

As for the future, the CERN Council (official delegates of the Member States) decided to set up a Working Group to study the Scientific and Technological Future of CERN (beyond LEP) under the Chairmanship of Professor C. Rubbia. This Group should explore various options, in particular for a second high energy collider housed in the LEP tunnel and providing proton-proton (proton-antiproton) and electron-proton collisions. The possible characteristics of this machine are illustrated in Fig. 9, while Fig. 10 gives aperspective view of the LEP tunnel with both LEP and the new collider LHC.

The energy of the proton-proton collisions which could be obtained would be 10 to 18 TeV depending on the magnetic field of the dipole magnets. With well-established present technology 6 T could be obtained while an appropriate R & D programme, which has been initiated by CERN and various European laboratories, could lead to 10 T, enabling the machine to reach the top energy of 18 TeV.

The Working Group chaired by C. Rubbia will present its final report to Council before summer 1987. Progress reports will be presented at regular intervals in-between.

All the activities reported above are based on a very strong international collaboration, involving physicists and experimental equipment from all over the world. This collaboration is currently extended also to the design and beam measurements of accelerators, as Fig. 11 illustrates.


TOTAL COST OF HEP
(CERN Member States)
Billion Sfs. (1984 Costs)
National Expenditure
CERN Programme
Contribution to CERN
Years

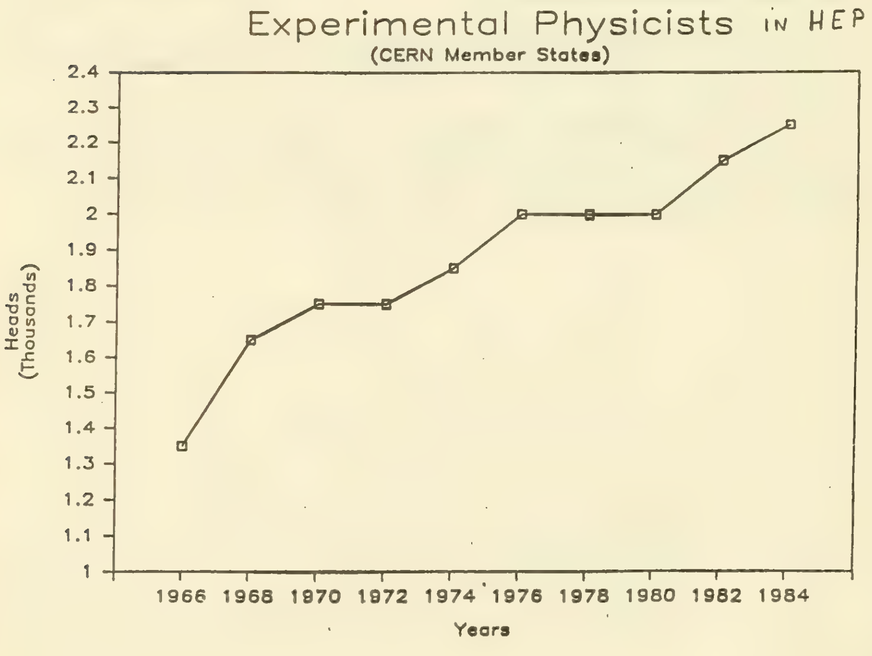

Experimental Physicists IN HEP
(CERN Member States)
Heads (Thousands)
Years

Fig. 1

Fig. 3

CERN – ACCELERATORS and RESEARCH PROGRAMMES

1. Synchrocyclotron (600 Mev) ~200 users

   Mainly on-line isotope separator(ISOLDE)

2. Low Energy Antiproton Ring (LEAR)

   $100 < p < 2000$ Mev/c ~300 users

3. SPS Fixed Target at 450 Gev/Light Ions

   ~700 u. 225 Gev/nucl ~120 u.

   Cycle of 14 s, $3 \cdot 10^{13}$ ppp

4. SPS proton-antiproton Collider (630 Gev)

   Max. Luminosity $0.35 \cdot 10^{30}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ ~300 u.

   Improvement Programme: $> 10^{30}$

5. Large Electron Positron (LEP) ~1100 u.

   Initial Beam Energy 55 on 55 Gev, which

   can be increased toward 100 Gev

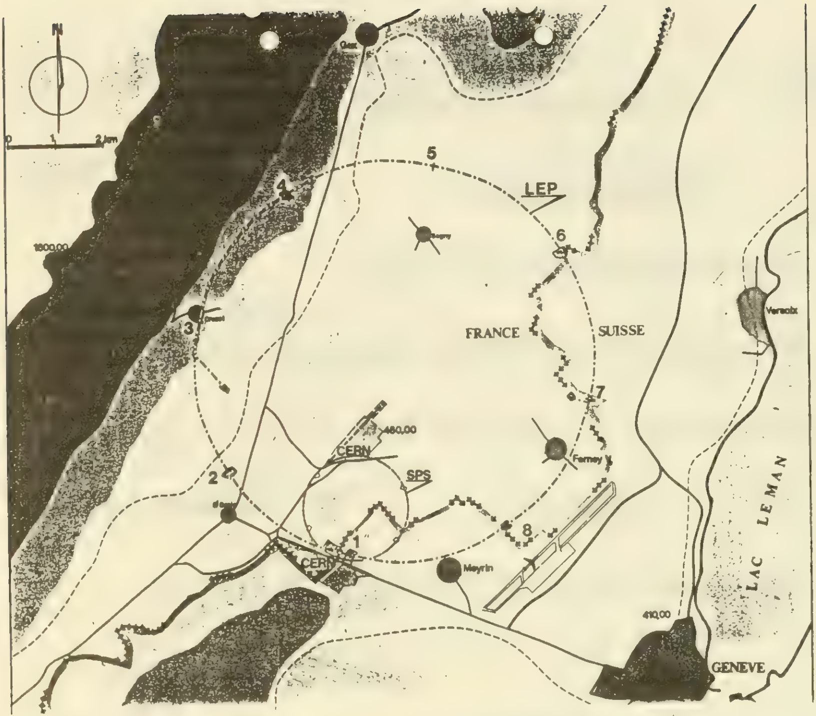

N
0
1
2 km
5
LEP
6
1600,00
3
FRANCE
SUISSE
7
Versoix
480,00
CERN
SPS
Ferney
2
8
1
CERN
Meyrin
LAC LEMAN
410,00
GENEVE

Fig. 4

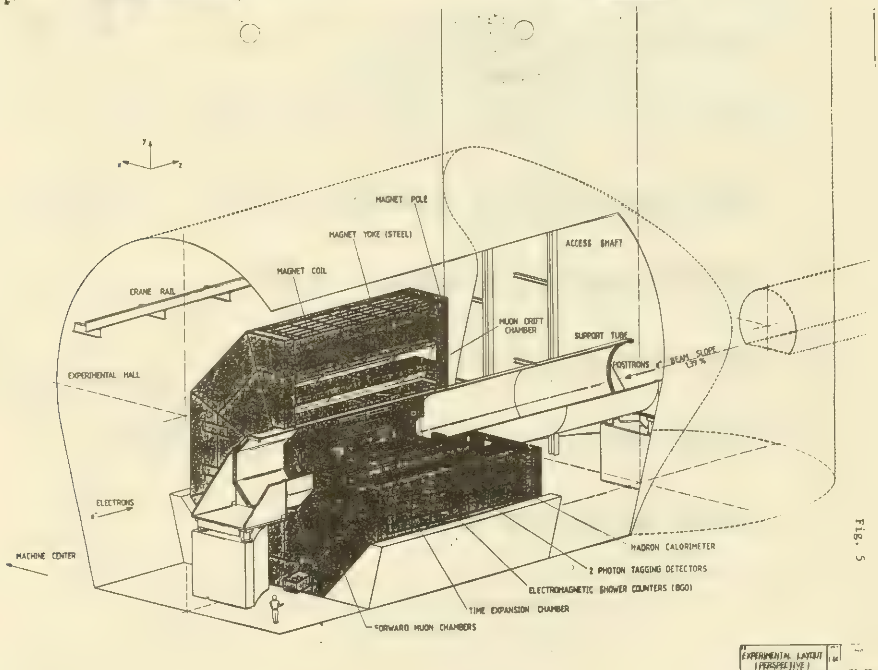

MAGNET POLE
MAGNET YOKE (STEEL)
MAGNET COIL
CRANE RAIL
ACCESS SHAFT
MUON DRIFT CHAMBER
SUPPORT TUBE
POSITRONS
BEAM SLOPE 1.39 %
EXPERIMENTAL HALL
ELECTRONS
MACHINE CENTER
HADRON CALORIMETER
2 PHOTON TAGGING DETECTORS
ELECTROMAGNETIC SHOWER COUNTERS (BGO)
TIME EXPANSION CHAMBER
FORWARD MUON CHAMBERS
EXPERIMENTAL LAYOUT (PERSPECTIVE)

Fig. 5

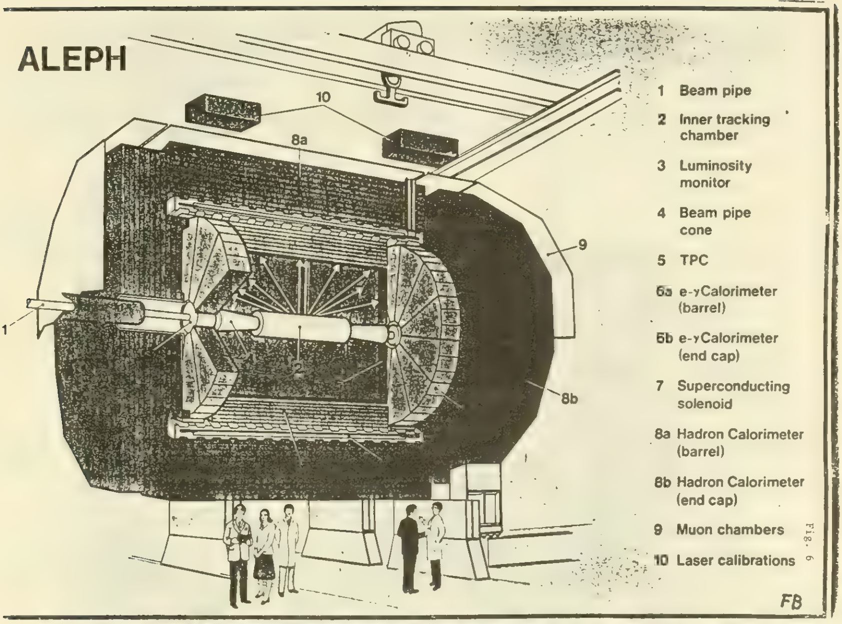

ALEPH
10
8a
9
1
2
8b
1 Beam pipe
2 Inner tracking chamber
3 Luminosity monitor
4 Beam pipe cone
5 TPC
6a e-γCalorimeter (barrel)
6b e-γCalorimeter (end cap)
7 Superconducting solenoid
8a Hadron Calorimeter (barrel)
8b Hadron Calorimeter (end cap)
9 Muon chambers
10 Laser calibrations
FB

Fig. 6

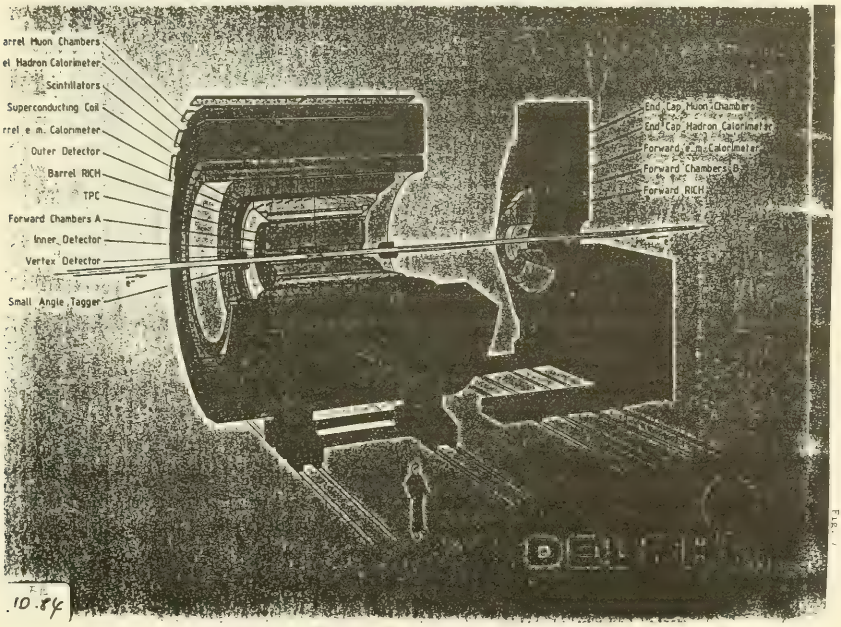

arrel Muon Chambers
el Hadron Calorimeter
Scintillators
Superconducting Coil
rrel e.m. Calorimeter
Outer Detector
Barrel RICH
TPC
Forward Chambers A
Inner Detector
Vertex Detector
Small Angle Tagger
End Cap Muon Chambers
End Cap Hadron Calorimeter
Forward e.m. Calorimeter
Forward Chambers B
Forward RICH
DELPHI
10.84

Fig. 7

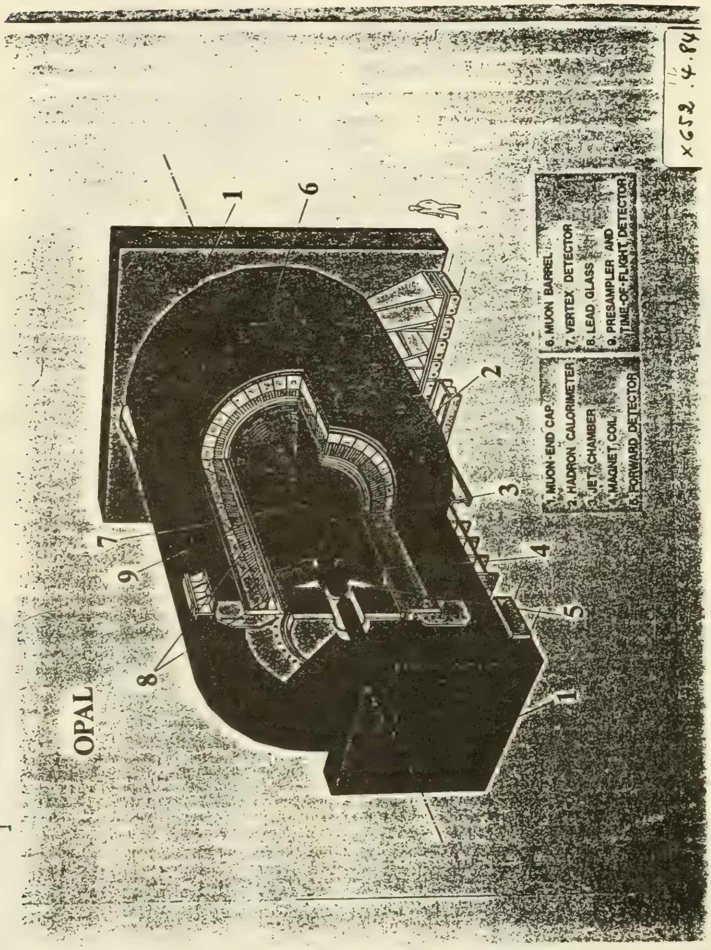

OPAL
1. MUON END CAP
2. HADRON CALORIMETER
3. JET CHAMBER
4. MAGNET COIL
5. FORWARD DETECTOR
6. MUON BARREL
7. VERTEX DETECTOR
8. LEAD GLASS
9. PRESAMPLER AND TIME-OF-FLIGHT DETECTOR
X652.4.84

Fig. 9

LONG TERM OPTIONS for

SECOND MACHINE in LEP

1. ONE-CHANNEL COLLIDER

$p\bar{p}$ E_{cm}= 10 to 18 Tev; L= 10^{31}-10^{32} $cm^{-2}s^{-1}$

ep E_{cm}= 1.2 to 1.8 Tev; L= 10^{31}-10^{32} " "

2. TWO-CHANNEL COLLIDER

pp E_{cm}= 10 to 18 Tev; L= 10^{33} $cm^{-2}s^{-1}$

ep (as for one-channel collider)

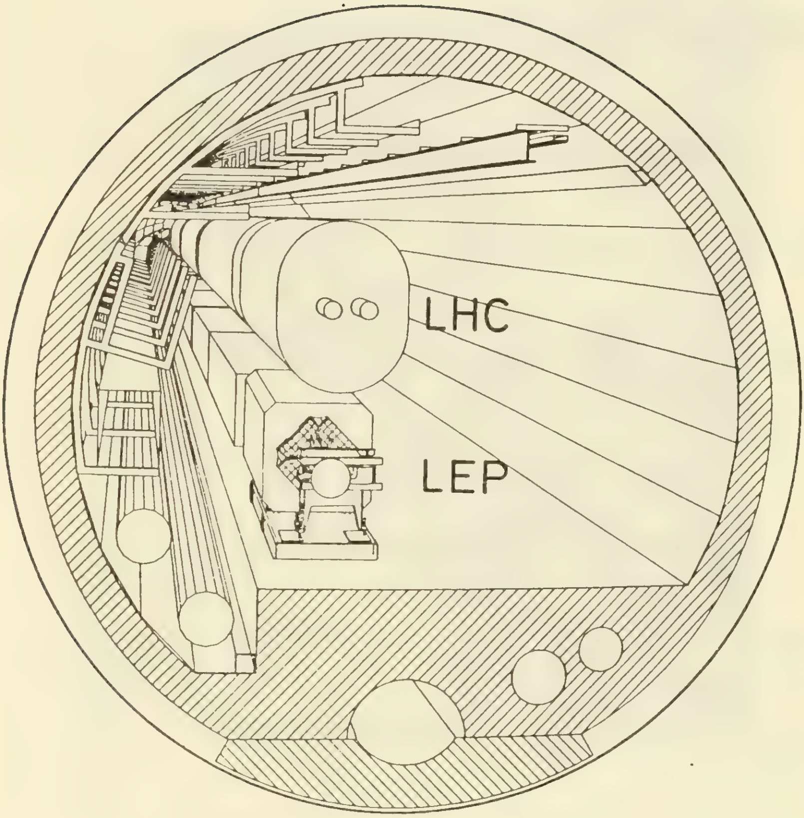
INSTALLATION & EQUIPMENT

EXISTING ON CERN SITE (prior to LHC)

1. Excellent Proton Injectors (PS & SPS)
2. Antiproton Source (AA+ACOL)
3. LEP Tunnel and Infrastructure

Fig. 10

DIR-TECH/84-01
May 1984



LARGE HADRON COLLIDER IN THE LEP TUNNEL

A feasibility study of possible options

by

The CERN Machine Group

Mr. FUQUA. Thank you very much.

The next presenter will be Dr. Leiss, Associate Director of High Energy and Nuclear Physics at the Department of Energy.

STATEMENT OF DR. JAMES E. LEISS, ASSOCIATE DIRECTOR OF HIGH ENERGY AND NUCLEAR PHYSICS, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC

Dr. LEISS. Thank you very much, Mr. Chairman.

As you know, I am representing Al Trivelpiece, who was given an offer he couldn't resist this morning, and so his loss is my gain, and I really do feel very proud. I think, as we all know, I am sitting here with the leadership of what I consider the very best laboratories in the world, and I am very proud of that. I think we should also recognize that as one of the very positive things about this field.

Mr. FUQUA. I was just commenting to Congressman Mineta a few moments ago that I hoped nothing happened in this room. It would be a severe setback to high energy physics.

Dr. LEISS. At least we would all feel that way.

Dr. SAMIOS. There would be lots of room at the top.

Dr. LEISS. That is right. [Laughter.]

I would like to make a few brief comments. As I understand, you have requested that I speak about two items. One is the status and plans of the U.S. high energy physics program, and the second is the Economic Summit international collaboration activities of the High Energy Physics Workshop chartered under the Summit. Let me first speak about the U.S. plans.

We know high energy physics is a curiosity-driven field at what I believe is the cutting edge of scientific research. It is driven by man's curiosity. It is also driven by a certain competitive spirit among scientists.

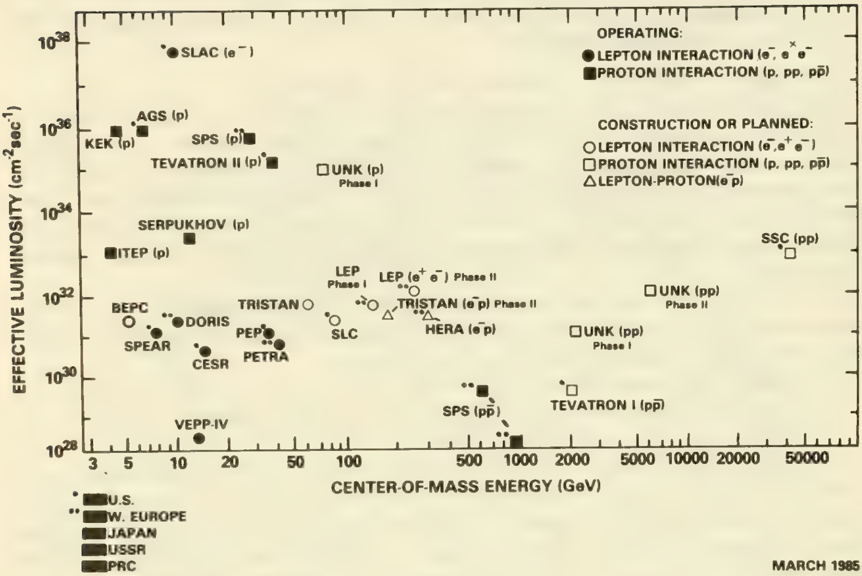
I think as we talk here, we need to recognize both of those features: it is curiosity driven; it is competitive driven. We want to increase international collaboration, but we have to remember those driving forces and preserve the good parts of them.

There is very close worldwide cooperation. I think the testimony you have heard so far here illustrates that. There are basically now two forums for discussion on collaboration, other than the individual scientist basis. One is the International Committee for Future Accelerators [ICFA], which is a scientific discussion forum.

The second is the Working Group on High Energy Physics set up under the Summit process which brings the political viewpoint into the discussion, and I think it is probably a good thing as we talk about larger and larger collaboration and larger facilities. There is excellent cooperation between our countries, as the various speakers have illustrated.

HIGH ENERGY PHYSICS

WORLD ACCELERATOR AND COLLIDING BEAM FACILITIES



Before talking about the U.S. program, if I could, I would like to show one Vu-Graph. We have passed a picture of this around so each of you has it. The purpose here is to try to illustrate at least some view of the worldwide complement of facilities where we plot on the left side the vertical axis, the effective luminosity—that is, the rate at which events occur in the machine—versus the center of mass energy that is available.

The various machines that have been discussed this morning and others such as the UNK facilities that are under construction in the Soviet Union are shown in this Vu-Graph to give a world perspective.

Off in the fuzzy region there of the Vu-Graph—maybe that is prophetic or something—the SSC is shown. It is both a high luminosity and a very high center of mass energy hadron-hadron colliding facility which would allow opportunities for research that do not now exist in the world.

But let me first talk about the present program. There are two major upgrade activities that have been going on in the U.S. program. The first of these is based upon a very major effort that the United States has expended in developing superconducting magnets of very high precision such as are required for the accelerator art.

I think the U.S. program recognized years ago that if hadron facilities were ever to go to higher energies, we simply had to face

the problem of learning how to develop that technology, and we have expended a fair amount of effort in that.

It is paying off now in the Energy Saver at Fermilab, where over 1,000 superconducting magnets are operating, doing research now with the fixed-target program, the Tevatron II, for about 1½ years and operating very successfully. It is being exploited also in the Tevatron I 1,000 GeV on 1,000 GeV proton/antiproton collider project at Fermilab.

The second point relative to international collaboration I would make here, supporting Dr. Brianti's comment, is that the stochastic cooling technique for accumulating enough antiprotons to give luminosity was a CERN invention that has been very helpful in the development, such as the superconducting magnet activities in the United States are helping other countries.

The second major activity that is underway in the U.S. program is at the Stanford Linear Accelerator Center, SLAC, where a new concept, the Stanford Linear Collider, is under construction.

This machine has two objectives. One is to see through the building of a large, interesting-sized model of a new type of accelerator facility, colliding beam facility, where one takes beams, makes them cross each other only once, but compresses the beam to such a small size that you still get luminosity, in other words, adequate events.

If that proves successful, then it will say that there is sense to go ahead with a major technological development effort which, some day in the future, would provide the basis where one might consider a large linear collider.

The second purpose, of course, is that the SLC is being built in an energy region where there would be extremely interesting physics to do at an early date. That project hopes to be finished in 1986.

These are the two major complements of the facility upgrade activities that are going on in the United States and that we believe will allow, together with our international collaborations that we engage in with other countries, for a healthy program for the next several years.

But we also have to worry about the long term. We are in an era where it takes probably a decade from the time you decide you would like to build a facility until the time you have it, and so we have to worry about what is going to be available in the mid to late 1990's and beyond the year 2000 for high energy physics.

That, of course, has led the High Energy Physics Advisory Panel to recommend to us that we initiate the activities leading up to the Superconducting Super Collider [SSC]. It is a large project, as you know. It is expensive. We are treating it very cautiously. I think that we are taking it seriously, as evidenced by the fact that we are expending appreciable funding in R&D for SSC.

I think, considering the size of the project and the interest in it, I believe it is going very well. Real progress is being made. Obviously, site selection is going to be a critical question. We have taken those actions to assure that various regions who have interest in the site are all being given a fair opportunity to compete.

Progress in selection of those magnet types is being made. A Reference Designs Study—a very excellent job was done by the study group last year—has put something firm behind the costs of the

machine. And so we believe that the progress directed toward a decision on what should be done about the SSC project is progressing very nicely.

If I could, I would turn now to the second topic that you requested we speak to, and this is the activities under the Economic Summit on High Energy Physics.

If I might, from my written testimony, I would like to read a few quotations from the overall Summit Working Group. These are statements by the heads of state of the Summit countries.

The first of these is a quotation, "Fundamental scientific research is one source of technological progress in industry and should be given support by governments."

"Science and technology are a source of national and international strength and can provide immense opportunities for revitalization and growth of the world economy. They should, therefore, be given consideration in all policy decisions for national development and international cooperation."

They further recommended that the heads of state ". . . take science and technology into account in their policy decisions and continue to include the subject on their agenda for future Summit meetings."

I think these illustrate that the heads of state both see that the development of science and technology is very important to the well-being of the countries individually and that there is a need for them to work together, for the countries to work together, on these developments.

One of the groups chartered for study of international collaboration is in the area of high energy physics. Of course, as you can see from the discussions here, high energy physics collaboration has gone on actively for a long time, and so there is a fair amount of framework of both formal and informal international agreements and cooperations between countries and between individual laboratories.

I think the thing that the Summit process allows is the possibility of bringing the political side of the house into these discussions and bringing them to the attention of the heads of state when you see things that they might do to help foster cooperation.

There have been three meetings of the Working Group on High Energy Physics, one in Washington in October 1983, a second in Brussels, Belgium, in July 1984, and the most recent of these in Cadarache, France, in January of this year.

The report prepared from the Cadarache meeting is here. I believe you have copies of that, and I would like to suggest that be submitted for the record, sir.

Mr. Fuqua. I think that has been distributed. Without objection, it will be made a part of the record.

[The material is contained in app. 4.]

Dr. Leiss. If I could, I would like to read a little bit directly out of the report from statements agreed to by the countries at the Cadarache meeting and contained in their report.

"The Cadarache meeting discussed the reports of three subpanels which had been chartered at the Brussels meeting and reached several conclusions on long-range planning. The present set of new high energy facilities under construction, Tevatron and SLC in the

United States, TRISTAN in Japan, LEP at CERN, and HERA in the Federal Republic of Germany, are complementary and not duplicative.

"A clear need not met by the present generation of accelerators is the requirement to extend the energy range of hadron colliders. The SSC is the most advanced plan in this regard, and the Europeans are considering options in the LEP tunnel. Other open questions are a linear collider for electron-positron collisions and an electron-proton collider which could make use of the LEP tunnel.

"The required new and advanced facilities can be built and operated within broadly constant worldwide budgets, with some fluctuation during peak capital expenditure years. While further concentration of facilities is perhaps inevitable, more than one region with a forefront accelerator capability working effectively in high energy physics is essential.

"It is also essential that the limited number of unique facilities remain open to competent scientists from all over the world. Thus, it is considered of great importance to continue the discussion and planning on an intergovernmental level."

The report then goes on to speak to the subpanel reports on cooperation in technology, and we have heard a fair amount of discussion of that. It is active and it should and will continue.

It also spoke and essentially challenged the heads of state to recognize that there are administrative problems—visas, work permits, export control licensing, where you need to use these things in a detector for 10 years, and essentially no country allows you a temporary visa or entrance permit longer than 3 years—and many problems of that sort which are administrative things that hamper scientific collaboration in all fields, where the heads of state could do a valuable service to international scientific collaboration by trying to remove some of those barriers.

We believe the process is going well. Obviously, there are very difficult problems. Each region has its own ambitions. It has its plans and commitments. How far it will go in terms of world accelerators built together I don't know how to foretell. I believe that the one thing that is clearly coming from this is a relatively high assurance that unwise duplication of facilities in the world will not occur.

Thank you, sir.

[The prepared statement of Dr. Leiss follows:]

Presentation to the House Science & Technology Committee

Task Force on Science Policy

on

STATUS AND PLANS OF HIGH ENERGY PHYSICS

by
Dr. James E. Leiss
Office of High Energy and Nuclear Physics
U.S. Department of Energy
Washington, DC

April 25, 1985

High energy physics is a field at the forefront cutting edge of basic research. It explores new physical domains which have never before been accessible for investigation. The U.S. program is internationally recognized for its excellence and the Department of Energy is pleased to have the lead role for Federal support and planning for this effort.

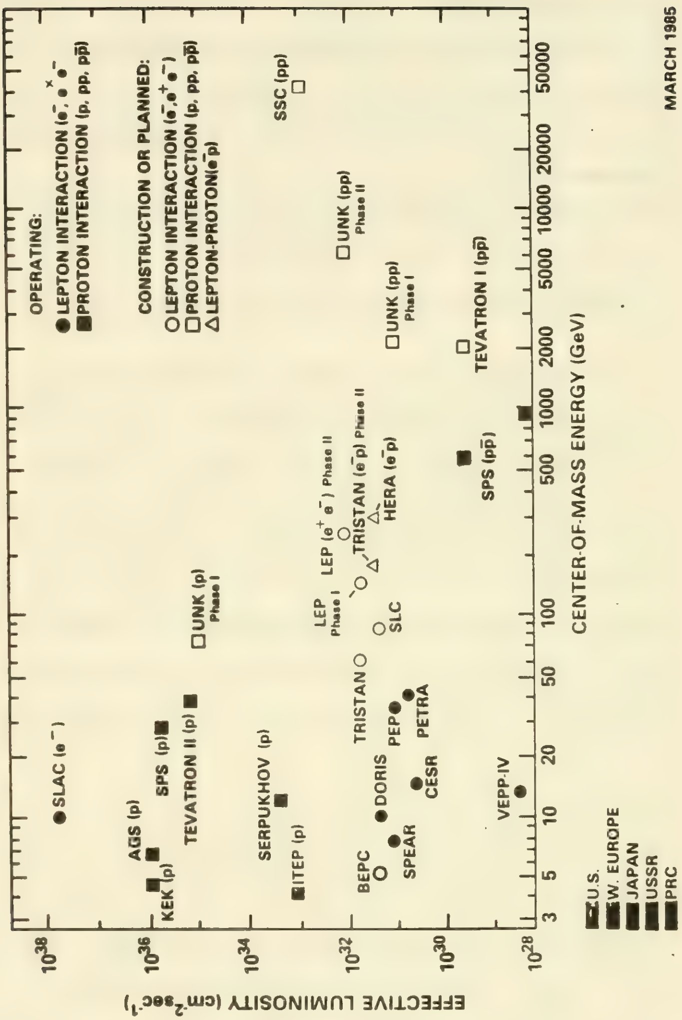
Experiments in high energy physics require the use of very large, expensive particle accelerator facilities, which are necessarily few in number. There is close collaboration on a worldwide basis in the planning of high energy physics facilities to ensure that the new major facilities have complementary capabilities and avoid unnecessary duplication. A major scientific forum for such discussion is the International Committee on Future Accelerators (ICFA) and the Economic Summit process has provided a political forum for discussions. High energy facilities are available throughout the world to qualified users on the basis of the scientific merit of their proposals, without charge for beam time and without consideration of their nationality. There is a long history of excellent collaboration with the major Western European centers at CERN and DESY and with Japan, largely arranged on an informal basis between the laboratories. We also have a formal agreement with Japan as a part of the

US/Japan energy agreement. Collaboration with the People's Republic of China and the USSR is also carried out through formal bilateral agreements of collaboration. Before proceeding to describe the U.S. program, I would like to place the U.S. facilities in a worldwide perspective by showing a viewgraph (Figure 1) which indicates the uniqueness of the capability of each of the world machines in terms of their energy and luminosity (a measure of the rate at which interactions occur). The facilities are color coded to indicate the geographic area of each facility.

Substantial progress has been achieved in recent years in our understanding of the fundamental constituents of matter and the basic forces in nature. We now have a solid framework, the Standard Model, which incorporates a synthesis of three of the basic forces in nature and a picture of matter as composed of various combinations of a small set of basic constituents, called quarks and leptons. Despite the great successes of the Standard Model, its description of nature is incomplete and there is clearly much left to do. There are very fundamental, important questions that cannot be answered without further experimental observations.

The successes to which I briefly alluded have been achieved with the present set of accelerators and colliding beam machines. The DOE-supported U.S. facilities include the Fermilab facility which until recently operated at 400 GeV for fixed target experiments; the SLAC facilities, which include fixed target experiments with beams of 32 GeV electrons from the Linac, the 4 GeV on 4 GeV SPEAR electron-positron colliding beam facility, and the 15 GeV on 15 GeV PEP colliding beam facility; and the AGS proton synchrotron at BNL which provides 30 GeV

HIGH ENERGY PHYSICS
WORLD ACCELERATOR AND COLLIDING BEAM FACILITIES



protons and 26 GeV polarized protons for fixed target experiments. In addition there is the CESR 8 GeV on 8 GeV electron-positron collider at Cornell University supported by the National Science Foundation.

There is a two-fold plan to attack the new physics frontiers which must be explored to uncover new insights and expand the horizons of new understanding. For the near future, the mid- to late-1980s and early 1990s, we are nearing completion on a set of upgrades to existing facilities. At Fermilab, the first step of this program was the fabrication and installation of nearly 1000 superconducting magnets in the main ring tunnel to raise the energy capability of the accelerator to near 1000 GeV, and at the same time reduce electric power requirements and cost. The superconducting magnet ring, a truly major, pioneering technological effort, has been successfully operating for physics research at energies up to 800 GeV for over a year and a half. The remaining phase of the Fermilab upgrades which are presently under way include the upgrade of experimental facilities to handle fixed target experiments with the higher energy secondary beams made possible by 1000 GeV protons and the provision of the antiproton source and experimental facilities to permit collision of 1000 GeV protons with 1000 GeV antiprotons. These two phases of the Tevatron are progressing well and should be fully operational by FY 1987.

At SLAC, we are constructing the Stanford Linear Collider (SLC) as an add-on to the SLAC Linac. A major purpose of SLC is to test important aspects of the technical feasibility of a new concept for electron-positron colliders which is essential to extend this domain of research to significantly higher energies than are currently economically feasible.

SLC will also give U.S. physicists early access to the important and exciting physics made possible by copious production of the Z° particles which were recently discovered at CERN.

Although these upgrades will permit exploration in new physical domains and exciting new discoveries, they cannot permit exploration of the TeV mass scale where breakthroughs in understanding and new phenomena are expected. The Standard Model, in its present form, cannot provide a valid description of nature in the TeV mass range. Something must change as we enter this new domain. Access to the TeV mass scale will test the Standard Model in this entirely new domain never before explored and point the way towards a better and more encompassing description of the fundamental nature of matter and energy.

This brings us to the longer range aspects of our planning, from the mid- to late-1990s and into the next century. In July 1983, the High Energy Physics Advisory Panel (HEPAP) unanimously recommended the immediate initiation of a multi-TeV high luminosity proton-proton collider project with the goal of physics experiments at this facility at the earliest possible date. After reviewing the recommendation of HEPAP and its 1983 Subpanel on New Facilities, the Department initiated preliminary R&D in FY 1984 to more clearly define the technical characteristics, cost, and scope of such a facility, now called the Superconducting Super Collider (SSC). These early studies, primarily through the Reference Designs Study, confirmed the technical feasibility of the SSC and provided a credible cost estimate for SSC construction. R&D and design studies are continuing in FY 1985 and the Department has requested funding for a continuation of SSC R&D in FY 1986. These studies will result in cost-optimized designs for the SSC and provide refined cost and schedule estimates.

The SSC is clearly crucial to continuing progress in high energy physics for the mid-1990s and into the next century. The SSC is, however, a large and expensive project and the Department is taking a very cautious approach to carefully understand the full costs and broad implications of proceeding prior to seeking authorization to construct the SSC. Efforts presently under way in this R&D phase will contribute important input to the Department's decision process.

Looking further into the future is very difficult. The Department, as always, is supporting a variety of efforts in long-range advanced technology R&D to study and develop new concepts and techniques that will permit particle accelerator and detector facilities that have greater capability to explore new physical domains while at the same time being achievable on an economically feasible basis.

In summary, I am proud to be able to report that the U.S. program is healthy today, that we have under way a program of facility upgrades to ensure a world-competitive U.S. progress for the next decade, and we have initiated steps toward a future facility which could carry us beyond the mid-1990s and into the next century. Thank you, Mr. Chairman, for this opportunity to appear before the Committee today.

Mr. FUQUA. Thank you very much. I am sure we will be discussing that more in the discussion period.

Our next presenter will be Prof. Jean Sacton, Inter-University Institute for High Energies from Brussels, Belgium. He is also chairman of the European Committee for Future Accelerators.

STATEMENT OF PROF. JEAN SACTON, INTER-UNIVERSITY INSTITUTE FOR HIGH ENERGIES, BRUSSELS, BELGIUM, AND CHAIRMAN, EUROPEAN COMMITTEE FOR FUTURE ACCELERATORS [ECFA]

Professor SACTON. Mr. Chairman and members of the committee, ladies and gentlemen, I am pleased to be here to present to you a very short overview of the activities of the European Committee for Future Accelerators.

This committee was created at the initiative of the CERN DG, at that time Vikki Weisskopf, in December 1962, in order to study the desirable development of high energy physics in Europe.

It has worked within its present format since 1966. By the present format, I mean that it is a two-bodied thing. One is the so-called Plenary ECFA, and the other one is an executive body, Restricted ECFA.

In Plenary ECFA, we have representation of each member state of CERN. There are 13 national high energy communities. The representation of the different countries is directly in proportion of the size of the high energy physics community of the different countries. This body meets twice a year. It is an open meeting which takes place at CERN.

The executive body, Restricted ECFA, is composed of a German and one representative per member state. In addition, we have the pleasure to have the CERN DG and the director of DESY. This body meets every 2 or 3 months at CERN, at DESY, or in the member states.

ECFA represents a community of the order of 2,000 experimental physicists and about 1,000 theoreticians. The terms of reference of this committee are to discuss the general policy of high energy physics development in Europe and to formulate recommendations in order to prepare for the future.

In order to do that, it is making a continuous review of the high energy physics activities in Europe. This means not only the CERN and DESY Programs but also the national plans and also the university activities.

This last point is of great importance for two reasons. One is the question of the manpower formation. It is in the universities that we will find our young physicists and engineers, and also because many of the problems we have to attack need a multidisciplinary approach, and in the university that is the best environment to find these sorts of people.

In order to achieve this review, we are organizing meetings, workshops, and conferences. It is fair to say that ECFA has no links with the governments. It has extremely good connections with the two international laboratories in Europe, CERN and DESY, and indeed, the chairman of ECFA is a member of the Sci-

entific Policy Committee of these two organizations. As I told you, the two directors attend our meetings very regularly.

For a long time, ECFA has promoted the idea that Europe should have two international laboratories offering to the European physicists complementary facilities. In this context, ECFA has played an essential role in deciding about LEP and HERA. In order to do that, we organized a series of meetings and a study group between the builders and the users in order to help fix the machine parameters and to define the scientific programs.

Among some of the other achievements that ECFA has been doing in the last few years, I would like to mention that we are regularly reviewing the needs and the available resources for high energy physics in Europe. By that I mean not only the question of finance but also the question of manpower and technical support.

One of the recommendations of ECFA has been to promote vigorous home activities. As I already told you, the contacts with the universities are of primary importance for us. In this context, also, ECFA has been a prime mover in developing European computing links and networks.

Indeed, if you want to do physics at a distance, it is the best way to do it, and this would save and guarantee the future of the high energy physics in the universities. This becomes, also, extremely essential within the development of the very huge collaboration, international collaboration, that our field knows.

As a result of these activities and their effects, I can tell you that Europe has a very strong and diversified program which goes up to the early 1990's. You have heard the plans of CERN and DESY. It is fair to mention, also, that among our plans we have to include participation in the U.S. activities, and this is especially true at Tevatron I and Tevatron II, which are now becoming unique facilities for which we have not a correspondent in Europe.

As I told you, part of the preoccupation of ECFA is to prepare for the long-term future. I would just like to mention two recent initiatives that ECFA has had in order to prepare for this long-term future. One has already been tackled by Giorgio Brianti.

In 1984, CERN and ECFA organized a workshop on the feasibility of a large hadron collider in the LEP tunnel. I would not surprise you by telling you that one of the first conclusions of that meeting was that a large hadron collider is an essential facility that we will need in the near future, and we can guarantee first class physics.

The practical output of our meeting was that there was no basic technical obstacle in order to build such a machine in the LEP tunnel. Of course, one of the constraints is the real dimension of the tunnel, which implies for us that we should launch as soon as possible a program of research and development of high-field magnets. When I said high-field magnets, I mean 8 to 10 Teslas.

Indeed, one of the followups of this workshop has been that CERN, under the initiative of Giorgio Brianti, launched such a program in Europe in a sort of collaborative effort in order to tackle this problem.

The coming generation of machines—and when I am speaking of this, I have in mind LEP, SLC, HERA, SSC, and all these things—is based on extrapolation to higher energies of known acceleration

techniques. But it has now become clear that the long-term future of high energy physics is strongly linked to the development of novel ideas on how to reach even higher energy without increasing excessively the dimension of the machines and the cost.

In this period, the second initiative I want to mention of ECFA has been the organization of a workshop on the generation of high fields for particle acceleration to very high energies. At the occasion of this workshop, we were pleased to see that the understanding of many of these processes is now well underway, and even more, that we are starting to do some experimental tests.

One bad conclusion we had in Europe was that we noticed that Europe was not on the front line on these activities; that, on the contrary, a big effort was made in the States in order to develop these new techniques for acceleration of particles.

Therefore, one of the major efforts at ECFA that we will do in the near future will be to promote in Europe theoretical and experimental work on these topics.

Again, as a practical consequence of this meeting, we had the pleasure to see that some activities are now starting in France and in Italy to complement the two projects which were already under way, one in DESY and the other one in the United Kingdom.

The question of international, interregional collaboration will surely be tackled in the next meeting, but I would like to tell you that very recently we have recognized the fact that ECFA should not work by itself but should try to make some contact with the other communities of high energy physicists, and we are now negotiating between HEPAP and ECFA the possibility of there being regular exchanges, for example, having observers to our meetings.

On the practical side, I can say, also, that steps have been taken in order to put together the two communities who are looking at the very important problems of computing links and networks.

Thank you.

Mr. FUQUA. Thank you very much.

Our final presenter will be Prof. Boyce McDaniel, who is director of the Laboratory for Nuclear Studies at Cornell University and a member of the International Committee for Future Accelerators.

Professor, we are pleased to have you here and receive your remarks.

[The biographical sketch of Dr. McDaniel follows:]

DR. BOYCE D. MCDANIEL

Boyce D. McDaniel was awarded the B.A. (1938), M.A. (1940), and Ph.D. (1943) degrees from Ohio Wesleyan University, Case School of Applied Science, and Cornell University, respectively. He served as a staff member at the MIT Radiation Laboratory in 1943 and at the Los Alamos Laboratory of the Manhattan Project from 1943 to 1946. In 1946 he was appointed Assistant Professor at Cornell University, with successive appointments to Associate Professor and Professor. From 1960 to 1967 he held the position of Associate Director of the Newman Laboratory of Nuclear Studies at Cornell University. Since 1967 he has been Director of the Laboratory. While on leave in 1972, he served as Head of the Accelerator Section of the Fermi National Accelerator Laboratory, and again in 1974 as a group head within that section. For 12 years he was a member of the Board of Trustees of Associated Universities, Inc., and for 6 years a member of the Board of Trustee of Universities Research Association, Inc. He also served for 3 years on the HEPAP committee of the Department of Energy. He is currently a member of the International Committee for Future Accelerators of IUPAP. He is now serving as Chairman of the Board of Overseers for the Superconducting Super Collider (SSC) under the Universities Re-

search Association. He has served on numerous departmental and institutional review committees. As an experimentalist in nuclear physics, particle physics, and accelerator physics, he has worked in the fields of slow neutron spectroscopy, k-meson physics, electron-positron physics, and has played a major role in the construction of five election accelerator and storage ring facilities.

Fellow, American Physical Society, DPF.
Member, National Academy of Sciences.
Fulbright Research Award, 1953.
Fulbright Research Award, 1959.
John Simon Guggenheim Fellow, 1959.

STATEMENT OF DR. BOYCE D. McDANIEL, PROFESSOR OF PHYSICS AND DIRECTOR, FLOYD R. NEWMAN LABORATORY OF NUCLEAR STUDIES, CORNELL UNIVERSITY, AND MEMBER, INTERNATIONAL COMMITTEE FOR FUTURE ACCELERATIONS [ICFA], ITHACA, NY

Dr. McDaniel. Chairman Fuqua and members of the committee, I am pleased to have this opportunity to tell you about the activities of ICFA.

The acronym comes from its title, the International Committee for Future Accelerators. This is a committee of IUPAP, the International Union for Pure and Applied Physics, that sponsors many scientific activities and conferences.

Though there had been for a number of years discussions between representatives from various countries, the actual organization of ICFA was set up in 1976, and the basic mandate was as follows. I will read it: "To organize workshops for the study of problems related to an international super-high energy accelerator complex—VBA, the 'Very Big Accelerator'—and to elaborate the framework of its construction and of its use."

The second item is, "To organize meetings for the exchange of information on future plans of regional facilities and for the formulation of advice on joint studies and uses."

Since that date, ICFA has met a total of 11 times and has sponsored several activities which I will describe.

The regional composition of ICFA consists of three major blocks, each block having three representatives. These are the CERN member states, the Soviet Union, and the United States.

In addition, there is one representative from Japan and one from various nations associated with the Joint Institute for Nuclear Research at Dubna, and then there is a further representative to serve the remainder of the world scientific community. Currently, this latter position is a rotating position and is currently appointed to a scientist from India.

The chairman of the committee is chosen from the committee, and the chairman of the IUPAP Particles and Fields Commission is also an ex officio member of the committee.

Now, the initiation of this activity was based, of course, on the kinds of things that we are talking about here, namely that some day we would be wanting to build an accelerator which was so big that you could not do it by any national effort and that would require collaboration of all those people who were interested in high energy physics.

However, the question of size of what that facility is, at what point do you reach that stage, is one which has been changing through the years. At each point you sort of thought, well, this

must be it, and then there would be a new innovation which would allow you to make another reach with a great increase in expenditure.

Then, of course, there is always the question, Well, whose turn is it next? The guy who thinks he can get it regionally will always try to make his pitch, and then what you find is that one time it is one country that is sort of dragging its feet; another time, it is another country, and so forth. We have been through two or three cycles of that.

However, it seems to me that there is one of the things that has changed—a recognition, at least, of one changing factor—but we see that there isn't just one big accelerator; there are complementary accelerators. As we have seen, right now we are talking about a large electron collider, LEP. We have hadron colliders and now the HERA machine, which is an electron-proton machine.

So we have not been able to establish a real scenario for the future yet, at least in terms of the VBA, and so the VBA concept has not become the issue. The real issue is how can we present a full program and one which is nonredundant and proceed to provide all the tools that we need.

Now, ICFA established in 1977 a Super High Energy Facility Study Group for the purpose of examining the technical, organizational, and scientific problems pertaining to large accelerators. A total of three major workshops was set up. These were quite important. They have had influence on the choices, the decisions, and our research and development efforts.

The names of these were "Possibilities and Limitations of Accelerators and Detectors" held at Fermilab in October of 1978; the same title for another meeting in CERN in 1979; and then "Superconducting Magnets for Accelerators" at the Institute for High Energy Physics in Serpukhov in 1980.

In addition to these, there is establishment of a very important principle having to do with guidelines for experimental use of interregional facilities. We have already heard reference to it. These guidelines are given in some of the attachments to my testimony, but the main content is the following:

> The selection of experiments and the priority accorded to them will be based only on the scientific merit and the technical feasibility of experiments, and on the capabilities of the experimental group and the availability of resources needed to carry out the experiments.
>
> The operating laboratories should not require the experimental groups to contribute to the operating costs of the accelerators and collider or of their experimental areas. However, it is recognized that if the participation of teams from the other regions becomes excessive, the operating laboratories might be obliged to limit that participation after discussing the matter with the authorities in the other regions and with the other operating laboratories.
>
> Over a sufficient period of time, it is expected that a rough balance would be established between the utilization of the new front-line machines by the different regions.

These guidelines are being observed, and this action has been a very significant precedent in high energy physics.

In addition to the cooperative steps described, there are a number of significant steps in the cooperative funding and operation of major detection equipment at various laboratories. We have already heard various earlier speakers refer to that, and I

think there is no point in saying more except to say that it is a very widespread mode of operation and is clearly quite successful.

In 1982, after extensive deliberations by the HEPAP panel of the Department of Energy, it was decided that the SSC was the top priority for construction in the United States, and also, you have heard earlier today about the large hadron collider which has been conceived of as the plan for Europe, for CERN, and so at the time of the announcement of the United States interest in the SSC at the meeting in Fermilab of ICFA, it became a very important point of discussion.

After consideration and a lot of discussion about that, it was decided to hold a rather larger meeting last year in Kyoto in Japan in which some 100 high energy physicists from all over the world came to discuss this problem and to readdress the question of just what was the role of ICFA.

At that point, the ICFA group reformulated the guidelines, and I will read again. The new guidelines were: "To promote international collaboration in all phases of the construction and exploitation of very high energy accelerators." Its purpose is to assist and facilitate in accelerator design and construction.

Part of the statement is: "To organize regularly world-inclusive meetings for the exchange of information on future plans for regional facilities and for the formulation of advice on joint studies and uses."

Third is: "To organize workshops for the study of problems related to super high energy accelerator complexes and their international exploitation, and to foster research and development of necessary technology."

Now, a more complete statement that was made by the committee says, "Based on the consensus of the participants in the KEK seminar, ICFA views its major current role as facilitating the construction of high energy accelerators and not as arbitrating among various national or regional options."

I think in this regard there is a real distinction between ICFA and ECFA, ECFA being the European group, because they have reached agreement on their plans for the Europeans in the past and presumably in the future.

Now, in terms of the response to the recommendation for workshops, ICFA has established four panels, one on superconducting magnets and cryogenics, one on beam dynamics, one on new accelerator schemes, and one on future instrumentation and innovation.

There are workshops now planned during the coming year for that. Another innovation that is proposed is an international school for detector design and construction. We already have cooperation in the field of accelerator schools, accelerator design, between CERN and the United States. We also have our own national programs. But now it is pointed out that these detectors are, themselves, so complex, and there is such a wide variety of information available and so much work going on, it is important that we teach people how to do that.

So that is essentially the status of ICFA and where we are at the moment. We will be meeting again in October 1985 in Brussels.

Thank you.

[The prepared statement of Dr. McDaniel follows:]

INVITED TESTIMONY BY

Boyce D. McDaniel
Member of U. S. Delegation to the
International Committee for Future Accelerators, (ICFA), of the
International Union of Pure and Applied Physics, (IUPAP)

BEFORE THE

Science Policy Task Force
Committee on Science and Technology.
U. S. House of Representatives

STATUS AND FUTURE PLANS OF ICFA
the
INTERNATIONAL COMMITTEE FOR FUTURE ACCELERATORS

April 25, 1985

STATUS AND FUTURE PLANS
of the
INTERNATIONAL COMMITTEE FOR FUTURE ACCELERATORS

Mr. Chairman and Members of the Committee, I am pleased to have this opportunity to describe to you the activities of the international science organization called ICFA and its relation to the question of international collaboration in "Big Science," particularly with respect to High Energy Physics.

ICFA is the acronym for the International Committee for Future Accelerators. It is a committee of the parent organization, the International Union of Pure and Applied Physics (IUPAP), which coordinates, internationally, various scientific activities and conferences. The ICFA committee was set up in 1976 with the mandate

(a) to organize workshops for the study of problems related to an international super-high energy accelerator complex (VBA, i.e., "Very Big Accelerator") and to elaborate the framework of its construction and of its use;

(b) to organize meetings for the exchange of information on future plans of regional facilities and for the formulation of advice on joint studies and uses.

Since the date of its formulation, ICFA has met a total of eleven times and has sponsored several activities which I will describe.

The regional composition and current members of the committee, as allocated, are given in Attachment I. There are three major blocks--the CERN member states, the Soviet Union, and the United States. In addition, there is one representative from Japan and one from among the various nations associated with the Joint Institute for Nuclear Research at Dubna, USSR. There is a further representative to serve the remainder

of the world scientific community. Currently, this rotating position is occupied by a scientist from India. The ICFA Chairman is normally chosen from the Committee and the Chairman of the IUPAP Particles and Fields Commission is an ex officio member of the Committee.

The initiating impetus for the formation of ICFA was the recognition of the possibility that the science of High Energy Physics might one day require the construction of an accelerator facility, the scope of which would place it beyond the capabilities of any of the separate regions now active in the field. It appeared to be appropriate to anticipate such a date by investigating the scientific, technical, economic, and organizational problems connected with world-wide collaboration in the construction of such an accelerator. This accelerator was referred to as the "Very Big Accelerator" (VBA). It is with this goal in mind that the original mandate quoted above was established.

One of the issues is the question of the size of facility which meets the definition of VBA. As time has passed, because of various innovations in the technology of accelerator construction, the regional capabilities for achieving ever-increasing energies have thus far been adequate. It has further become apparent that in order to satisfy the needs of the field, complementary facilities of different types are required and that the concept of a single "Very Big Accelerator" does not meet the need. For these reasons, it has been difficult to achieve, within ICFA, agreement on a scenario for the future. In the meantime, however, ICFA has accomplished a number of very important things.

ICFA established, in 1977, a "Super High Energy Facility Study Group" for the purpose of examining the scientific, technical, and organizational problems pertaining to a super high energy accelerator (VBA).

A total of three major workshops were organized. These were very productive and have had an important influence on our views of large accelerators and have in fact affected the course of accelerator development since that date. The following workshops were held: "Possibilities and Limitations of Accelerators and Detectors" held at Fermilab in October 1978, then again at CERN in October 1979; "Superconducting Magnets for Accelerators" at the Institute for High Energy Physics in Serpukhov, USSR in June 1980.

Another very important action of ICFA was the establishment of guidelines for the experimental use of interregional facilities. These guidelines were subsequently endorsed by all the major high energy physics laboratories in the world. The full text of these guidelines is given in Attachment II appended to the submitted testimony. The main content may be described in the following terms:

> The selection of experiments and the priority accorded to them, will be based only on the scientific merit and the technical feasibility of the experiments, and on the capabilities of the experimental group and the availability of the resources needed to carry out the experiments. The operating laboratories should not require the experimental groups to contribute to the operating costs of the accelerators and collider or of their experimental areas. However, it is recognized that if the participation of teams from the other regions becomes excessive, the operating laboratories might be obliged to limit that participation after discussing the matter with the authorities in the other regions and with the other operating laboratories. Over a sufficient period of time it is expected that a rough balance would be established between the utilization of the new front-line machines by the different regions.

These guidelines are being observed by the laboratories and this action has set a precedent for significant international cooperation in high energy physics.

In addition to the cooperative step described above, in recent years there have been significant steps in the cooperative funding and operation of major detection equipment at various laboratories. As the field has matured, the detection devices have become more complex and expensive. Individual experimental collaborations frequently involve institutions from several different countries. It is now rather common that the experimentalists from the different countries commit themselves to provide various components of the detector. These arrangements appear to have been quite successful.

In 1982, after extensive deliberations, the High Energy Physics Advisory Panel of the Department of Energy recommended, as its top priority, the construction of a very high energy hadron colliding beam facility called the Superconducting Super Collider (SSC). Because construction of such a facility would influence the plans of other countries and laboratories, the announcement stimulated intense discussion at a meeting of ICFA held at Fermilab in August 1983. As a result of this discussion it was decided that it would be appropriate to have a broader discussion of the role of ICFA with regard to interregional planning for accelerator facilities. A one-week seminar was scheduled to be held at the Japanese high energy physics establishment, KEK, at Kyoto in May 1984. The title of the seminar was "Future Perspectives in High Energy Physics" and it was attended by about 100 leading physicists invited from all parts of the world.

At this seminar there was a survey of the various activities and plans of the high energy physics community throughout the world, followed by an intensive discussion of the role which ICFA should play in the planning of the next generation of accelerators. The outcome of these

deliberations was formulated in a revised statement of the role to be played by ICFA as given below:

(a) to promote international collaboration in all phases of the construction and exploitation of very high energy accelerators;

(b) to organize regularly world-inclusive meetings for the exchange of information on future plans for regional facilities and for the formulation of advice on joint studies and uses;

(c) to organize workshops for the study of problems related to super high energy accelerator complexes and their international exploitation, and to foster Research and Development of necessary technology.

In a more complete statement of the conclusions of the meeting the following point was made: "Based on the consensus of the participants in the KEK seminar, ICFA views its major current role as facilitating the construction of high-energy accelerators and not as arbitrating among various national or regional options."

In response to the recommendation for workshops, ICFA has now established special panels to arrange activities in the following areas:

(a) Superconducting Magnets and Cryogenics
(b) Beam Dynamics
(c) New Accelerator Schemes
(d) Future Intrumentation Innovation and Development

Workshops are being scheduled in each of these fields for the coming year. The proposed programs are comprehensive and involve a broad participation by the community of experts. While a joint accelerator summer school has already been established by CERN and the United States, it is proposed that a similar international school under ICFA auspices be established for training in the design and construction of detectors.

A summary of recent activities of ICFA prepared by the ICFA secretary, W. O. Lock, is given in Attachment III. The next meeting of ICFA is scheduled for October 1985 in Brussels, Belgium.

In summary, I feel that ICFA is a useful organization which has the primary role of providing a public forum for discussion of issues of international cooperation and maintaining effective communication between the various regional domains of activity in high energy physics. Efforts are currently being made to make it more effective in support of the goals of the field.

Attachment I

REGIONAL COMPOSITION AND MEMBERSHIP OF ICFA

April 1985

Chairman:

V. L. Telegdi (Eide. Technische-Hochschule, Zurich, Switzerland)

Secretary:

W. O. Lock (CERN, Geneva, Switzerland)

CERN Member States:

J. Sacton (Universities of Brussels, Brussels, Belgium)
H. Schopper (CERN, Geneva, Switzerland)
V. L. Telegdi (Eide. Technische-Hochschule, Zurich, Switzerland)

JINR Member States Other than USSR:

N. Van Hieu (National Center for Scientific Research, Hanoi, Viet Nam)

USA:

B. McDaniel (Cornell University)
L. Pondrom (Univ. of Wisconsin)
N. Samios (Brookhaven National Laboratory)

USSR:

E. Myae (Institute for High Energy Physics, Protvino)
A. N. Skrinsky (Institute for Nuclear Physics, Novosibirsk)
V. A. Yarba (Institute for High Energy Physics, Moscow)

Japan:

Y. Yamaguchi (Univ. of Tokyo)

Fourth Region:

P. K. Malhotra (Tata Institute of Fundamental Research, Bombay, India)

Chairman of IUPAP Particles and Fields Commission (ex officio):

L. D. Soloviev (Institute of High Energy Physics, Protvino)

Attachment II

9 July 1980

Guidelines proposed by ICFA for the Interregional

Utilization of Major Regional Experimental Facilities

for High-Energy Particle Physics Research

(Agreed by ICFA at its Fifth Meeting held at CERN on 9 July 1980)

- Considering that in the future major experimental facilities for high energy particle physics research, notably the very largest particle accelerators and colliding beam machines, are likely to be few in number, probably only one of each type of the very highest energy and that these machines will be located in different regions of the world,

- And recognizing that experimental physicists from all regions will wish to gain access to these few machines in order to pursue their research,

- ICFA proposes that the regional laboratories operating these facilities should adopt a common policy towards experimental physicists from other regions seeking to use the facilities they operate. The guidelines proposed are as follows:

1. The selection of experiments and the priority accorded to them are the responsibility of the Laboratory operating the regional facility.

2. The criteria used in selecting experiments and determining their priority are:

   (a) scientific merit

   (b) technical feasibility

   (c) capability of the experimental group

   (d) availability of the resources required.

3. It is expected that teams from other regions will normally wish to join with local regional teams to form experimental groups in proposing and carrying out experiments using a regional facility. The national or institutional affiliations of the teams should not influence the selection of an experiment nor the priority accorded to it.

4. The availability of the resources needed for the experiment are examined at the time of selection of the experiment (see 2 (d) above). The contributions of each team and of the Operating Laboratory to an experiment are the subject of agreements drawn up between the Operating Laboratory and the authorized leaders of the teams in the experimental group. When appropriate, realisation of the proposals approved may be effected within the framework of bilateral and multilateral agreements in force or newly reached arrangements.

5. Operating laboratories should not require experimental groups to contribute to the running costs of the accelerators or colliding beam machines nor to the operating costs of their associated experimental areas.

6. It is expected that averaged over a reasonable period of time the application of guideline 2. above will lead to a balanced use of the major new facilities by the regions concerned. However, if at any time an Operating Laboratory finds that the participation of teams from other regions in their experimental programme is becoming excessive, the Operating Laboratory may be obliged to limit that participation. Any such action should be accompanied by discussions with the relevant authorities of the regions concerned and consultations with the other operating laboratories subscribing to the Guidelines laid down in this document.

Attachment III

12 February 1985

RECENT ACTIVITIES OF THE INTERNATIONAL COMMITTEE FOR FUTURE ACCELERATORS, ICFA

By W.O. Lock, CERN, Geneva - ICFA Secretary

ICFA is the International Committee for Future Accelerators, set up by the IUPAP Particles and Fields Commission in 1976, the first meeting being held in the summer of 1977. It is composed of 14 members from the different regions of the world, distributed as follows: CERN Member States 3; USA 3; USSR 3; Member States of JINR (Joint Institute for Nuclear Research, Dubna) other than USSR 1; Fourth Region 1; People's Republic of China 1; Japan 1; the Chairman of the Particles and Fields Commission is an ex officio member. The present Chairman of ICFA is V.L. Telegdi of ETH, Zurich.

ICFA arose out of a series of East-West meetings to review future perspectives in high-energy physics which took place at Riga (1967), Semmering (1968), Tbilisi (1969), Morges (1971), New Orleans (1975) and Serpukhov (1976). At the last two meetings specific recommendations were made which directly led to the establishment of ICFA with the following mandate :

"To organize workshops for the study of problems related to an international super high energy accelerator complex (VBA) and to elaborate the framework of its construction and of its use.

To organize meetings for the exchange of information and future plans of regional facilities and for the formulation of advice on joint studies and uses".

In fact, in the little over seven years of its existence (August 1977 to the present), ICFA has been active on the first topic and has organized three workshops, viz.:

Two on "Possibilities and Limitations of Accelerators and Detectors" (Fermilab, U.S.A., October 1978 and Les Diablerets, Switzerland, October 1979)

and one on "Possibilities and Limitations for Superconducting Accelerator Magnets" (Protvino, USSR, October 1981).

It has also drawn up guidelines for the use of accelerator facilities built in one region of the world by research physicists from other regions. During 1981 these guidelines were accepted by the Directors of all of the world's major high-energy laboratories, which effectively means that the complete range of facilities is available to physicists from any country, the only criteria used in selecting experiments to be carried out being scientific merit,

technical feasibility and the capability of the group proposing the experiment.

At an ICFA meeting held at Fermilab in August 1983, it was realized that the second task of ICFA as defined above had been somewhat neglected, especially in view of recent developments of planned and projected accelerators in different regions of the world (e.g. the large electron-positron collider at CERN, the 3 TeV proton synchrotron UNK in the USSR and the single-pass linear collider in the USA as well as the recently suggested 20 TeV proton synchrotron (SSC) also in the USA). It was therefore decided to postpone a fourth workshop which had been scheduled to take place at the Japanese National Laboratory for High Energy Physics (KEK) in May 1984 and instead to organize a Seminar on "Future Perspectives in High Energy Physics", along similar lines to those held earlier, and particularly that of New Orleans in 1975.

The Seminar took place from 14 to 20 May 1984 and was attended by about a hundred participants, mostly senior scientists from Eastern and Western Europe, USA, and Japan, including the Directors of almost all the major high-energy physics laboratories, and representatives from Australia, Canada, China, India, Mexico, South Korea and Vietnam.

The first part of the Seminar was devoted to a survey of accelerators now under construction (see Table I) and of those currently being designed or under consideration (see Table II). This was followed by a number of talks on the physics possibilities at higher energies, on the associated experimental techniques to be used and on some technological aspects of accelerator construction, such as superconducting magnets.

The second part of the Seminar was organized as a series of panel discussions on ways and means of encouraging more interregional collaboration both in research and development work and in accelerator construction. As a results of the various debates, ICFA was able to arrive at three major conclusions which were unanimously endorsed by all the Seminar participants at a final plenary session. These were :

1. that ICFA sees its major role as facilitating the construction of high energy accelerators and not as arbitrating among regional options;

2. that ICFA should sponsor international panels on Superconducting Magnets and Cryogenics, on Beam Dynamics, on New Accelerator Schemes and on Future Instrumentation Innovation and Development to coordinate work in these fields;

and 3. that ICFA should convene seminars at regular intervals to review the status of high-energy physics and to anticipate future activities.

Table II

FUTURE ACCELERATOR FACILITIES BEING DESIGNED OR UNDER CONSIDERATION

Name or description	Location	Particles	Energy
Superconducting Super Collider SSC	USA	pp, $p\bar{p}$	20+20 TeV
Hadron Collider in the LEP Tunnel	CERN, Geneva	pp, $p\bar{p}$	Various options 5+5 TeV to 9+9 TeV
Large Linear Collider (LLC)	SLAC, USA	e^+e^-	1 + 1 TeV
VLEPP	Novosibirsk USSR	e^+e^-	Stage 1 150+150 GeV Stage 2 500+500 GeV

<u>Note</u>: Only the SSC has been the subject of detailed design studies thus far.

At its most recent meeting, held in Leningrad in October 1984, ICFA appointed the Chairmen of the four panels listed above. These are, respectively, G. Brianti (CERN), N. Dikansky (Novosibirsk), A. M. Sessler (Lawrence Berkeley Laboratory) and T. Ekelof (Uppsala). The membership of the Panels is now being constituted and it is hoped that they will be able to present their draft programmes of work to the next ICFA meeting which is planned to be held in Bombay in April 1985.

Accelerator facilities now under construction

Name	Location	Particles	Energy	First operation for physics (estimated)
BEPC	Beijing, China	electrons and positrons	2.8 + 2.8 GeV	1988
TRISTAN	KEK, Japan	electrons and positrons	30 + 30 GeV	1986
SLC	Stanford, USA	electrons and positrons	50 + 50 GeV	1987
LEP	CERN, Geneva	electrons and positrons	Initially 50 + 50 GeV then 100 + 100 GeV	end 1988-early 1989
TEVATRON I	Fermilab, USA	protons and antiprotons	1 + 1 TeV	end 1986-early 1987
HERA	DESY, Germany	electrons and protons	30 + 820 GeVp	1990
UNK	Serpukhov, USSR	protons protons	600 GeV 3 TeV	1990 1992-93

ICFA GUIDELINES:

AS APPROVED BY IUPAP, 1976.

The aims of this committee should be:

--To organize workshops for the study of problems related to an international super high energy accelerator complex (V.B.A.) and to elaborate the framework of its construction and its use.

--To organize meetings for the exchange of information on future plans of regional facilities and for the formulation of advice on joint studies and uses.

AS MODIFIED AND PROPOSED, APRIL 1985, BY ICFA FOR ACCEPTANCE BY IUPAP AT ITS NEXT MEETING IN KYOTO, JAPAN, IN AUGUST 1985.

--To promote international collaboration in all phases of the construction and exploitation of very high energy accelerators.

--To organize regularly world-inclusive meetings for the exchange of information on future plans for regional facilities and for the formulation of advice on joint studies and uses.

--To organize workshops for the study of problems related to super high-energy accelerator complexes and their international exploitation, and foster Research and Development of necessary technology.

DISCUSSION

Mr. FUQUA. Thank you very much, Professor.

Now we have five very fine discussants, and I would like to introduce them at this time: Dr. Leon Lederman, who is director of the Fermi National Accelerator Laboratory in Illinois; Dr. Burton Richter, whom I have already mentioned, director of the Stanford Linear Accelerator Center in Stanford; Prof. Jack Sandweiss, Yale Physics Department, and chairman of the Department of Energy High Energy Physics Advisory Panel, HEPAP; Dr. Nicholas Samios, director of the Brookhaven National Laboratory in Long Island; and Prof. Maury Tigner, director of the Universities Research Association, Superconducting Super Collider Central Design Group, at Lawrence Berkeley Laboratory in California.

We are very happy to have all of you gentlemen. We will have some questions, so feel free to jump in and express yourselves if you feel that you could elaborate on any of the things.

I will start out with a real easy one. I guess probably the largest facility ever proposed, the SSC or Superconducting Super Collider, is under serious consideration not only in this country but other places, and its proponents, which probably are sitting in front of me, say that it will enable scientists to penetrate further into the ultimate structure of matter.

I might say it also has its critics who say that the cost is too high for the science expected. What I would like to ask is, in your view, is it a device which is needed not only for research in physics but also to signal our continued commitment to U.S. leadership in science? Or will it be like the SST, the supersonic transport, 20 years ago, a device which was technically feasible but so expensive that the resources could probably be used in other places?

Who wants to jump on that easy one? Leon.

Dr. LEDERMAN. I like the SST analogy because, if you will remember, with the SST, there was always another way of getting from point A to point B. It took a little longer, but you could get there.

I think the point with the SSC is that there is no way—and we have beating our heads against walls for now 6 or 7 years—of finding any other way of getting the information that the SSC is designed to get.

We are following the scientific dictates of the theory as we understand it, and it points to a machine of roughly those parameters, and we can get hints from all kinds of avenues, from our astronomer friends and from other experiments we are doing now, but we all feel, I think, that there is widespread consensus, which I think is worldwide, that these particular kinds of parameters, the rough parameters of the SSC, are necessary if we are ever going to get a complete understanding of the nature of matter and energy.

As far as the first part in which you asked if this was too expensive, the answer is that we are, I think, horrified and, as people not usually noted for humility, a bit in awe of the price. We are determined to try to reduce the price if we can, but we confess that we don't know any dramatic way of doing that, and it is, in perspective, about four times more expensive than any other project of this kind.

I guess Fermilab was the biggest project. But it is a logical progression of our progress in understanding the nature of the world that goes all the way back to the beginning of science, so we believe in it, and we think it is an essential scientific imperative.

Mr. FUQUA. Would anyone else care to comment?

Professor TIGNER. I would like to add to Dr. Lederman's comment. I certainly agree with what he says. However, I would like to remind us that in fact this science as it has been pursued historically—and we now have a long history of pursuing this fundamental search for what is it that makes the material world what it is, how we can understand the diversity and complexity which we see in simpler terms, that has been a generator of wealth for us, both intellectual and technological, for many, many years.

So we have a strong historical precedent for understanding exactly what the merits of pursuit of this kind of science are. This generation of wealth has both been in the primary scientific knowledge that has been sought. Dr. Lederman addressed himself to that.

Certainly our understanding of the world around us has progressed, and the technological and cultural consequences of that we are all now well aware of, since we have been engaged in its pursuit since well before the turn of the century. We know about the tremendous advances in technology in our electronics and chemistry, materials, and so forth, that have flowed from trying to understand the fundamental makeup of the world.

In addition, however, to that primary generation of the pursuit of this science comes other intellectual spinoffs, you might say. The methods, the intellectual methods, that have been devised to understand the data that was generated by the experiments have worked to great advantage in helping us to achieve the primary understanding that we seek. But they have also been applicable in other fields of science and even other areas of physics and beyond physics, and that has characterized the pursuit of this science ever since its beginnings, and it has not stopped.

For example, the most recent example would be the lattice gauge theory which was developed largely, or motivated largely, by the pursuit of understanding high energy physics, but has also turned out to be an extremely powerful method for understanding many other physical phenomena and will have use in condensed matter physics and all the technology that flows from that.

In addition to those intellectual primary and secondary benefits or generations of new wealth are technological things. We heard of this very nice study that Dr. Brianti explained to us about CERN, that even in real time, so to speak, the expenditures following this kind of science generate economic utility for the infrastructure that supports the economic infrastructure of the particular region of our country that supports this.

The surprising thing is it is not only in electronics and computers, which has the highest economic utility, but on his pie diagram, you will see that even in classical things like the working of steel there have been advances generated by interaction with high energy physics activities, to say nothing of electrical equipment and vacuum and cryogenics.

Now, that same sort of thing, of course, happens throughout the world where the interaction takes place between the primary science and the technological infrastructure of a region or country.

In addition to these, you might say, immediate benefits, of course, there are also the spinoffs that come from the application of the technology that is developed to do the high energy physics to some completely new field that no one has thought of in the past. The superconducting magnets and materials, for example, that have recently been developed have already found major commercial and other scientific and medical uses. That has been the story of this business in the past.

Both the detector technologies have found application widely outside the field of high energy physics, and the accelerators themselves have proven to be very important economic instruments. There is now an enormous medical and materials inspection processing business which was generated by our ability to make accelerators, these accelerators originally having been developed to do this science.

So I think it is clear that the pursuit of basic particle physics has been a continual generator of new wealth for our society and for our economy ever since its beginning, and I don't see any reason why we should assume that that will not continue to be the case.

Mr. FUQUA. Let me ask our international guests, does the rest of the world high energy physics community agree with the U.S. high energy physics community that the SSC or similar facility is of the highest priority?

Professor SOERGEL. I would like to say something to this question. For the various questions which are now pressing in particle physics, we need several approaches, experimental approaches, so we need several accelerators.

There is general agreement amongst the community of particle physicists that a very high energy hadron collider is one of the machines which is really wanted in the next time. You can see this also from the fact that people—I am not talking in the United States about a large hadron collider, but also at CERN, for instance, like Dr. Brianti outlined.

We particle physicists are all delighted at how well the hadron collider at CERN has worked, what good physics it seems to give, and we are all looking forward to the higher energy collider which the Tevatron will give us in this next year. And so we are hopeful that there is a good road to really promote particle physics with these hadron colliders.

Apart from colliding hadrons, there is another point here that, for technical reasons which are not so much technical but are in the nature of the particles, the protons are heavy, and that is a reason why we can accelerate them to much higher energy with present-day techniques than we do with electrons.

We are working on electron colliders, but to reach the energies which are available to hadron colliders, which seem to be available with our technologies, they will not be available probably for some time for electrons. So a hadron collider is a very natural and logical step to go really to very high energies.

I would like to comment also a little bit to the question of the technology. The history of particle physics has seen technological

development which brought the cost of the accelerators, compared with what they do, down considerably. The latest and biggest step in this game was the development of the superconducting magnets to build big accelerators.

This superconducting technology now seems to be interesting to industry. We have managed with our new project, with the HERA project, to get industry in Europe and industry in Germany very interested in this technology, and I think industry realizes that application of superconductivity on a large scale is a potential technology for later years, even if they don't know at this moment where it will be applicable outside of high energy physics. Is there really an application? I am quite sure that such tremendous phenomena must have a real practical application.

These big machines are the first testing grounds to apply this interesting technology on a real large industrial scale and make high demanding technological approaches in industry. I think it is a very important element, and we have experienced this already now in European industries, that it is accepted.

Mr. FUQUA. Well, another question that comes up that I think this group could be very helpful with is whether there has been an overinvestment in high energy physics relative to the subfields of physics or maybe other disciplines. Would somebody care to comment about that?

Professor SOERGEL. I think one could talk about overinvestment only if either the facilities which we make would not produce good scientific results or would not be utilized to a reasonably good extent.

If I look around in the world at what are the real big facilities, they are only very few, and as far as I can see, all of them have given good results and have been used very well.

In the United States, you have a number of excellent examples. We have the Brookhaven Lab accelerators of old age, yes, which are still producing very interesting physics and have produced a great number of big discoveries.

You have the Fermilab machine in the United States which has made very important discoveries and is now getting a very new life as a new single source of superconducting magnets. I could name also the lab at Stanford where I think all the investments have paid off scientifically, exceedingly well, or at Cornell.

So in this country, I don't see that you have really overinvested. I don't think we have overinvested in Europe with our machines. We have, by the way, in Europe a philosophy—Dr. Brianti pointed out to me it was the same in DESY—that we try to make all of our previous investments fully usable for the next machines.

In the HERA accelerator, for instance, we use all the existing accelerators on site, which is an important big investment, which are phased out as primary research tools, and they are essential pieces of the injectors of the new machines. So does CERN, so does SLAC, of course.

I don't think there is an overinvestment.

Mr. FUQUA. Dr. Brianti.

Dr. BRIANTI. More or less on the same tone, I showed to you the graph of the total spending on the high energy physics in Europe.

This is CERN plus national expenditures, which in fact went down and leveled off.

This was done by giving full priority to forefront facilities, and it was done by sacrificing national facilities or facilities which ceased to be on the forefront, although still very productive, and could not be compared in priority to future ones.

The example is that when the CERN Council agreed to the construction of LEP, this was under the clear condition that the budget of CERN should have remained constant during those years, and to achieve that, we had to close down a unique facility such as the proton-proton collider, ISR, which worked for 10 years and then it was to be closed down. It was very productive still scientifically. We had to close down various parts of equipment in experimental areas and so on and devote the resources which were available to this big construction.

This is true, as already the previous discussant has said, concerning U.S. labs. So the field has been characterized by facilities always progressing but not adding up to all the ones which were kept to simply continue routine work. There was a clear priority decision taken by the community and by the laboratory in this direction.

Thank you, Mr. Chairman.

Professor SOERGEL. Can I still make another comment?

Mr. FUQUA. Yes.

Professor SOERGEL. You very well know that high energy physics in this past decade has had an enormous, tremendously good time with very exciting discoveries. I think all that we do with investments should keep this pace, so that the thing remains interesting and remains interesting also for the young generation of people to keep them scientifically motivated.

If you will allow me 2 minutes, I will tell you a story which I think is interesting in this context. There was a big discussion in Europe as to whether the SPS should be built, which was a machine of similar size as the Fermilab machine, and we had problems in my country to convince the Government.

We had a high industrial chief of one of the big chemical firms. We invited him to CERN and showed him around, and when he had seen the scientists and seen the machine which gives the young people the chance to do experimental work, to do exciting work, to train them to do this exciting work, he said, "Send some money. It is very well spent. Let's do it." This visit switched the German Government to do this.

Mr. FUQUA. Dr. Sandweiss.

Professor SANDWEISS. Thank you. Maybe I could just say before making my remarks that I very much appreciate the opportunity to take part in this discussion to you and to your colleagues.

What I wanted to say about this question was really very similar to what Professor Soergel and Dr. Brianti have said. When you try to compare sciences in different fields, how do you make the relevant measure of investment? That really is the question you are asking.

That can only be done, in a sense, by looking at each individual science itself and asking what is needed in that science in order for it to prosper, to be healthy, to make the progress which is possible

to make in the science. I believe, if you look at it that way, high energy physics in fact has very definitely not been overinvesting. In fact, because it is expensive, I think we feel a need to be very responsible and I would even say tough, perhaps austere, even, in our facilities.

The history of high energy physics facilities very much shows that. The number of facilities that have been terminated, not because they haven't been doing good work but because they haven't been doing perhaps the very most cost effective work, is very large, and I believe that the SSC, for example, although it is very large, is a machine which, by the measure of what is required in order to keep a viable pace in the field, is one that is even austerely required, although I know the absolute number is very large.

Thank you.

Mr. FUQUA. Yes.

Dr. LEISS. I would like to put a comment in on these. I think we can, and we do, yearly, as best we know how, show you some of the spinoffs and benefits in addition to the science that comes from the programs in high energy physics, although I think you can get in trouble with that because then you get one science saying, "Are my spinoffs better than your spinoffs?" and you don't know how to measure that.

It seems to me, though—I refer to the declarations that came from the heads of state in the Summit process on the importance of science and technology development in their countries and the recognition that our economic well-being and, indeed, our economic competitive posture in the world, speaking provincially as the United States, rests upon science and technology.

I think the real dilemma that we have or you have to face, really, is not so much one big facility and one field; it is the fact that many fields, in order to make progress, have large facilities they would like to have.

It is a little bit paradoxical that if you look at those facilities, every one of them you can think of is coming as a result of high energy physics developments for them, which at least shows some measure of what we do.

It seems to me the issue that really eventually has to be faced is, have we reached the point where we cannot afford the tools that are required to further our understanding of the laws and composition of nature? Frankly, I shudder at the thought of the impact of that on our bright young people, if we decide we have reached that point.

Mr. FUQUA. Mr. Brown.

Mr. BROWN. Mr. Chairman, I would say first that I regard this as an absolutely unique occasion. I don't recall at any time during my experience on the committee that we have had such a large and capable group of scientists representing a single field of science appear before us. I am sure this occasion will remain long in my memory.

The reason for, of course, inviting you is not entirely because of our deep concern for high energy physics, important as it is, but because you represent a series of policy questions which extend across the whole field of science in terms of the relationship of Government and Government funding to branches of science where

there are important policy issues and important opportunities, and where we have to resolve questions of allocating resources in some reasonable fashion.

I want to thank both the panel and the chairman for making arrangements to make this meeting possible.

Of course, looking back at the history of the last couple of generations from the time of the Bush Report with regard to the importance of supporting basic research up to the present time, we have continuously throughout that time grappled with the problems we are raising today: What portion of our resources should be devoted to promising fields; how should it be distributed amongst various fields of science; what is the relationship between the funding of the large science expensive projects and maintaining a base of small science and science education, and so on?

You all, in your testimony and your experience, throw a great deal of light on these kinds of policy issues. We look at this question of are we putting too much into particle physics or high energy physics, and then we look at other fields of science—and I am reminded of molecular biology, for example, which we have been funding through the NIH now for 20 or 30 years—and the level of funding for basic research in the biological sciences has probably been comparable to today's level, around $3 or $4 billion now for a generation, and we can see the results of that rather consistent level of funding in terms of the marvelous things that are happening in molecular biology and biotechnology.

The reasons for continued support of that, of course, we frequently point out, have to do with the hopes of elderly Congressmen that this will help save our lives. [Laughter.]

We don't necessarily have that same connection with high energy physics. But it illustrates the importance of recognizing the need to have a link with the political process in some fashion, and you gentlemen have all pointed out some of those links—the spinoffs in cryogenics and vacuum technology and various other fields that are important to the society.

Of course, the fundamental reason that all of this research took place was the recognition of the vital contribution of science to the war effort during World War II. We would like to get away from that, frankly, and recognize the importance of this curiosity-driven aspect of science. But that is kind of hard to sell to a large public and, through the public, to the Congress. But this has been a most illuminating experience.

I have a couple of points that I wanted to explore with you just briefly, and I don't think we need to exhaust any of these things. But in the European community and in the Japanese situation, do you have a linkage between the scientific and the governmental communities that gives you assurance of a certain level of resource support, either in terms of a fixed number of dollars or a fixed portion of the Government budget or a fixed portion of the GNP or some other target that you are trying to achieve and have some commitment to? And is it desirable if you do have that, or if you don't have it?

Dr. Brianti. I don't know if I will be able to answer completely your question, but I wish to comment on the CERN situation.

As I said, CERN is an international organization in which the member states pay in proportion to their gross national product. This is reviewed on a 3-year basis.

Now, you may assume that because there are certain countries, it is an extremely complicated process how to arrive at a decision, and indeed, I am not saying that it is an easy process. It is complicated. But the fact that then it is an international commitment so far has helped us in being stable.

In other words, when there are major decisions which have been taken as to building new facilities, for instance the SPS—and this took almost 7 or 8 years to be decided upon—that took 5 or 6 years to be decided. But once it is decided, the member states feel committed.

For instance, in the case of the LEP construction which spans over 8 years—and 8 years is a long time—this was based on two foundations. The first was, OK, the budget is what it is, and don't ask for more; try to use the Swiss francs or the dollar the best you can. The second is a gentlemen's agreement, of course not a legal one, but a gentlemen's agreement among the representative of the member states that the level would be kept absolutely constant during those 8 years.

And so the national science budget may go up and down and there may be a local problem here and there, but the fact that it is an international commitment has rather helped the stability.

So on the disadvantages side, it may be that in order to reach consensus, you have to settle on a level which may be lower than the most wealthy country could support. But on the whole, we are pleased.

This continuity has occurred over 30 years. We figured out that in any given point in time, there is always one of the European governments that is either not there or elections are due to come, but the fact of the collegial responsibility has helped the stability.

That is the comment I wish to make.

Mr. BROWN. You would stress the importance, then, of having a reasonably long-term commitment to this?

Dr. BRIANTI. Oh, yes, this is essential, because, you see, this construction has a long-term basis.

Mr. BROWN. That differs from our practice here, which in most cases is annual decisions, but in fact we have established that same kind of commitment through inertia, perhaps, if nothing else.

Professor SOERGEL. Maybe I should comment on the situation in Germany. It is not just Europe, but since Germany operates the other high energy physics laboratory as a national lab in Europe, it may be relevant to your question.

We have for DESY a reasonably stable budget on which we can count over the years which goes roughly with inflation. The budget for DESY, as I have outlined, is given 90 percent by the Federal Government and 10 percent by the state government of Hamburg.

These two bodies have kind of a board of trustees which defines every budget, so it is officially given every year by vote in the two parliaments, in the Federal budget and in the state budget of Hamburg. But it is very stable over the years.

Now, when a new facility comes like the big HERA facility, which is a very large facility—it is one of the largest in the world

at this moment—we get an excursion from this budget which now takes for a few years over the construction, and then the budget is expected to go down to the level we have now before the HERA construction again, and we can count on that for its operation.

This ability, I think, is very important for the lab.

Mr. Brown. Could you comment, Dr. Ozaki?

Dr. Ozaki. Since I am not really a director of the laboratory and I am directing a project, I don't know how well I can comment on this particular issue. I am a scientist looking from the outside into the makings of government and the political system.

There has been a strong will, however, in Japan, to commit to the development of basic science in Japan lately, actually, and as you can see, the Government of Japan has approved and is supporting TRISTAN with a very large amount of money. Indeed, that is really true, but I see the evidence of their will to continue support.

However, the level of support which the pure sciences are getting in Japan is such that the TRISTAN project is draining the system quite a bit. Though it is increasing, looking at the current budgetary situation in Japan, I don't see a marked increase coming for several years.

Now, in looking at a project itself, for instance, the discipline itself, we do not have a specific commitment to a certain percentage of the total science budget allocated to some area, so it depends upon project by project. When a good project comes and is approved, then we are certain to receive that commitment over certain many years. Then we will most likely lose the support after the project is finished, with that money going into some other project like space or whatnot.

So I really don't know whether I have answered your question or not, but as the manager of the program, I believe it is very, very important to have a definite commitment extending over the years.

The Government of Japan also runs the same way as here. It is a year-by-year business. But for a long-term project like TRISTAN, I find that it is very important to have the specific commitment over the long term as to what the schedule is, the funding schedule is, and what are the total moneys. So far, I am not getting quite that kind of support.

Mr. Brown. Let me ask another general question for anyone to comment on.

You have referred to this field as being one that is curiosity driven, and I wonder if there is any way in which we can evaluate the amount of curiosity. Are we in a situation where we ought to be concerned about the number of people coming into the high energy physics field? Are there fluctuations, as there are in many other technical fields, which deserve to be considered in policy considerations over reasonable periods of time, say, 10 years? Do we suffer ups and downs of topflight, curiosity-driven scientists which impinge upon our capability to produce results in some of these activities?

Dr. Samios. Maybe I could comment in a different way. A field is driven, and bright people come in, by the excitement in the field, and the position we find ourselves in now is that—and there is usually a tradeoff of hopping back and forth between theoretical and

experimental aspects—sometimes one part gets ahead and then the other.

In a sense, if you find no experimental results, a field will dry up. Radioastronomy became a prominent field when people built things to look. Before that, you could speculate to your heart's content and not get anywhere.

High energy physics finds itself presently in a position where one has to look at the next mass scale. Theorists can speculate to their hearts' content, and the limits of their speculation are unlimited at the present time, and so which way you go, you cannot tell until you look.

And so, although one would prefer that one could know which way to go on a cheaper basis, we believe that we are at a roadblock until one builds some facility to look, and then one will have the further interplay.

So, as a result, you will find that over the last years we have had—I mean, one of the measures is bright theorists, for instance, and I believe that in the United States and Western Europe we are getting some of the very bright people still coming in the field. In the same sense, at Brookhaven, where we are a multidisciplinary lab, we get very bright people in microbiology. It is absolutely true.

But I believe what will happen, unless one gets these new experimental tools, that if one does not know which way to go, then you will see that reduction as a function of time.

Mr. Brown. Dr. Soergel.

Professor Soergel. Particle physics has developed from originally atomic physics, nuclear physics, in the search for even more fundamental constituents of matter. Happily, the bright young people went to the front line of research. Those which, 100 years ago or 80 years ago, would have gone to the atomic physics, and nuclear physics later, now come to particle physics.

We have to keep this curiosity-driven field interesting for the young generation. I personally believe that this is one of the most important spinoffs, if one talks of that, that young people from the universities can, as they have done in the past, do in a front-line research field like particle physics their studies, their Ph.D. work, before they become what I sometimes call, not completely seriously, useful members of society.

It is a very good forming of young people to work in high energy physics, so I believe you have a very important goal here for the society.

Before you addressed the question about the size of the accelerators. Unfortunately, there we have some things imposed on us by nature. We cannot make a smaller accelerator if it serves less people. The size of the machine is given by the physics. So we have to have a big machine to start off, and the only way we can do less or more is by its exploitation.

There high energy physics is different from many other fields like biology or solid state physics, where you have small installations but more in number. You realize that now in high energy physics we have already coordinated in such a way that we make one facility in the world of its kind, and all high energy physicists which want to do this kind of investigation which is possible in that facility go there.

All people who want to do very high energy proton-antiproton hadron collisions will go to Fermilab once Tevatron works. All people who do electron-proton collisions will come to Hamburg to do their research, and so on. But we need one big facility to go further down which is different for other fields.

Let me make another comment for the final thing. I think it is characteristic for the development of high energy physics, because we need this big apparatus, not only the big accelerators but also the big detectors. In order to operate these things, to build these things, we need large groups.

If one looks into the funding per scientist, then suddenly we see that the difference between high energy physics and other fields is not so extraordinary. That is at least my experience in my country. I don't know how it is in America. But if you take these figures, then high energy physics does not appear so terribly expensive.

Also, these large projects take a much longer time scale than the smaller projects did previously, and if you take all of this into account, I believe that then suddenly these figures become not so shocking any more.

Mr. BROWN. If you slice it into small slices, it doesn't hurt nearly as much, Doctor?

Professor SOERGEL. Yes. But I think it is correct to do it this way.

Mr. BROWN. Mr. Chairman, we have a bell ringing. I just wanted to yield to you to decide what to do here.

Mr. FUQUA. I have one final question which I want to ask Dr. Richter and Dr. Samios, because they could be affected.

When we get into big science, at the expense, maybe, of other ongoing science projects that are going on that—and I really get into how soon do we have to do this.

I recall arguments that have been made, for instance, in the space program when we had the project, the Viking, landing on Mars, that Mars would be there for a long time. There was no rush to get there. Also on the Galileo Program, there was no time certain that we had to try to have a landing on Jupiter because it would still be there for many, many years.

The particles will still be out there. Do you see that if we move into this at a rapid rate, that this will impact very valuable high energy physics or particle physics programs that are ongoing?

Dr. RICHTER. Well, the impact on the ongoing program is, of course, going to depend on the total level of support for the science.

It is interesting because this is a question that we were discussing most of yesterday with a group of us meeting with HEPAP. How much do you support what you might call regular ongoing programs versus how much do you put into the investment in the future? We have to do both. You always need investments in the future if the science is going to progress.

One of the things that makes life really tough in big science like high energy physics is that the development time for a major new facility is so long. It has gotten to be a lower bound of 10 years from a gleam in the eye to a machine working and experiments going.

Dr. LEDERMAN. A beam in the eye?

Dr. RICHTER. A gleam in the eye. [Laughter.]

And so we are thinking now about what kinds of facilities one needs in the middle nineties, in spite of the fact that Leon and I, in the next 2 years, are going to be turning on the U.S. frontier machines. We know we are going to have to make a step in the mid-nineties to keep the science going and to keep on answering the questions that are turned up by the work that is going on now and in the next 5 years.

I think it is very bad if one slows down the pace of science too much. If you slow it down too much so that the students cannot hope to feel that they are going to be ones that make the great discoveries when they grow up and get their Ph.D.'s and go out and run an experimental group, then the good students are not going to go into a discipline, and they are going to go someplace else.

It is not just curiosity-driven, but there is a sort of feeling, I think, in all good scientists that it is not purely curiosity for mankind, but it is curiosity for themselves. They want to know.

You have to keep the field moving fast enough so that the students can feel that they will make a discovery. Then you will keep getting the good ones in. If you slow it down too much, they are going to go someplace else.

Mr. FUQUA. Nick, kind of briefly, because we do have a vote.

Dr. SAMIOS. I will be brief.

I agree with what Burt said. I think one has to have a continuous process in getting to the new thing, because if you don't do that, you may not have people around to work on the new thing.

My comment on the SSC is that there is a natural time scale, and I think the time scale is now. The technology is in hand. We made a decision a few years ago at some pain to the field to really leapfrog and go to it. I think the science is there. If you push me and say, "Could you delay by a year?" the answer is obviously yes. If you push me and say, "Should we delay by 5 years?" then I think the whole project may not make sense because other things will come about or new ideas, or the commitment of the people for 10 to 12 years is a rather large commitment.

So my answer would be, Let's get on with it. It is timely; the technology is here.

The last comment I would make, since the bottom line is always budgets, I would say the high energy budget, if you look at it over the last 15 years, has not gone up. In fact, we went down rather drastically at one point.

I would say other fields have had increased appetites proper for the fields, and they are getting to our level, so there is a strong competition for funds in all of the sciences. If anything, I think our budget situation is worse off now than it was 15 years ago.

Mr. FUQUA. Gentlemen, on this we must conclude because we do have a vote now.

I want to thank you all very much. It has been a very enlightening meeting this morning. Like Congressman Brown, I think we have assembled one of the great panels in the whole world, and we thank you all for your contributions and for being here today.

Thank you very much. The task force will recess until further notice.

[Whereupon, at 11:15 a.m., the task force recessed, to reconvene on May 2, 1985, at 10 a.m.]

APPENDIX 1

Witnesses' Questions and Answers for the Record

Answer to the Questions for the Record of the Hearing, before the
Science Policy Task Force, April 25, 1985
Satoshi Ozaki, KEK

1. What is the future prospect for the international cost-sharing of the next generation of high energy physics facilities, both in terms of construction and operation?

As it was clear from the presentation by representatives from the U.S. and Europe, and of myself, the field of high energy physics has been quite international with many examples of cost-sharing experiments at world's major accelerator facilities and one example of major international laboratory, i.e., CERN. However, the high energy physics facilities of next generation are necessarily large and even the shared cost will amount to a major portion of, and in some cases in excess of the current funding for this field in each nation. It, therefore, will be imperative for a successful implementation of such a cost-sharing in question to give a proper consideration to the financial situation of the government and the benefit to the society of the countries involved. Needless to say, the initiative for such international cooperation must come first from the scientific community. As to the Japanese situation, we are putting an intensive effort to complete TRISTAN project in the fall of 1986 and have not yet arrived at a conclusion as to the future program in the high energy physics in Japan.

2. What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?

a) Advantages of cost-sharing:

The cost-sharing could reduce the financial burden of the nations involved in the big science and make it possible for scientists of the world to have access to a big facility which is essential for their scientific persuit, if those nations could reach agreement on a single configuration of facilities to be built by a common effort.

Another advantage would be found in maintaining the current spirit of internationalism in the field, which no doubt will be beneficial in strengthening the tie between nations.

b) Disadvantages:

Since multiple nations will be involved in a project, and since the funding required from each nation will most likely be sizable as was stated in the answer to the question 1, the initiation and execution of the program will require a multi-national agreement in the high level of the governments as well as a consensus of the scientific community of each nation involved. This no doubt will add another dimension of complexity on the project, possibly resulting in a delay of implementation.

A worldwide cooperation on one accelerator facility may present another disadvantage from a lack of competition between laboratories on which this field has thrived to date.

3. How many high energy physicists are performing research in Japan and how much funding is provided for high energy physics research?

Japan have about 450 high energy experimentalists including supporting engineering and technical personnel, accelerator specialists (110) and graduate students (120). Of these, about 100 physicists and accelerator specialists are involved in international collaborations at a varying degree of commitment for each individual.

The funding for high energy physics for current fiscal year is about 32 billion yen, of that 1.7 billion yen is ear-marked for international cooperations. A major fraction of the total funding is for TRISTAN construction.

4. What would be the best worldwide configuration of high energy physics facilities from the point of view of science? How might this best be determined?

Current objective in the energy frontier of this field is the study of phenomena in the mass range of 100 GeV using proton-antiproton colliding beam facilities (S$\bar{p}$pS at CERN, TEV-I at FNAL) and electron-positron colliding beam facilities (PEP at SLAC, PETRA at DESY, TRISTAN at KEK, SLC at SLAC, LEP at CERN). Some of the theoretical considerations and experimental indications suggest that the mass scale for the next generation is of the order of 1 TeV. Thus, the facility configuration best suited for studies in the next generation energy frontier will be at least one each of proton-proton or proton-antiproton colliding beam facility in 20-40 TeV range, and electron-positron collider in the vicinity of 1 TeV in total energy. An addition of electron-proton collider at very high energy would give us an insight of the structure, if any, of fundamental constituents.

In another frontier, namely that of high luminosity (or high intensity), 10-100 GeV class electron-positron collider with a very high luminosity would be of great benefit for a detailed study of phenomena in the corresponding energy region.

Although one might say that these facilities be concentrated in one geographical location for an added versatility, the reality of the facts is that, at least one of these facilities would have to be located in each geographical region of the world so as to maintain a high level of participation in the high energy physics by the world's scientific communities. After all, there is no international program without national program. This concern would also apply to a need of local accelerator facility to maintain an excellence of young people, students.

5. Should some or all future "big science" facilities be developed on the basis of international cooperation?

At present, we can only speak for the field of high energy physics in which, as was stated by the testimony of all those present at the hearing, there have been successful international cooperations as a matter of fact. A construction of a facility, may it be a major

detector or accelerator, on the cost sharing bases, can be effective only when the nations involved can reach an agreement on such sharing of a facility for their research purposes, with due consideration on the interest of scientific community, technical and industrial capabilities of the society and the financial situation of each nation.

6. What is the trend of international collaboration in high energy physics? Is it increasing, decreasing or remaining relatively constant?

I judge that the collaboration is increasing, at least in the experimental program and accelerator R/D, anticipating new opportunities at the facilities which is to become operational in near future.

7. What factors (a) facilitate or (b) inhibit international cooperation in high energy physics?

Owing to the open door policy of the U.S. high energy physics community and science authorities since early days of activity, many physicists from the world have enjoyed opportunities to participate in research at the U.S. research facilities. This, together with the fact that the research in this field requires a major accelerator and detector facilities has facilitated a growth of international cooperations to date. Prevailing open door policy in the U.S. and elsewhere, coupled with an understanding by the scientific community and the government of each nation involved is essential for an enhanced international cooperation.

Such spirit in Japan facilitated US/Japan collaborative experiments at two of four collision area at TRISTAN. One of these two collaborations includes small but significant participation from China and Korea.

As to the inhibiting factor, one can site a) constraints in the funding, though high energy physics, by and large, has been treated favorably compared to other field of study, and b) uneven localization of major research facilities. (Note, for instance, that the US-Japanese Coopration has become reciprocal in true sense only with the KEK's TRISTAN e^+e^- collider project.)

8. Does the rest of the worldwide high energy physics community agree with the U.S. high energy physics community that the Superconducting Super Collider or a similar facility is the highest priority?

In Japan, high energy physicists have not yet arrived at a conclusion as to the priority in future program in high energy physics. There are variety of opinions among the community on the future direction, including SSC and an electron-positron linear collider in 1 TeV region.

9. What does "world leadership" in high energy physics mean? What particular benefits accrue to the "world leader" versus "number two"?
Why should national policy makers care whether or not the nation is first, second or third in high energy physics research?

The high energy physics, which shows a high degree of intellectual determination and technical excellence of the society, can in turn contribute to the strengthening of the country's technological capability and competitivity. It would seem natural for a national policy maker to care about the growth of such a field for its scientific merit, technological spin-off, intellectual build up and, possibly, prestige, regardless of concern whether the nation is first, second or third.

10. Are the experiences of international cooperation in high energy physics directly applicable to other fields of science? What lessons may be learned?

Objective of the high energy physics is to understand the ultimate picture of the structure of matter and forces and is to satisfy an intrinsic and universal desire to know our environment. The field is, so to speak, the purest of pure science. In addition, the object of study and the method used are quite universal and the experimental study depends highly on large scale accelerator facility. These factors must have promoted a successful international cooperation to date.

The experiences obtained for high energy physics may be applicable to other field of science, if the characteristics stated above is clearly apparent with the field.

Answers to questions for the record
by V. Soergel

1. What is the future prospect for the international cost-sharing of the next generation of high energy physics facilities, both in terms of construction and operation?

Answer: To answer this question, one should distinguish accelerator facilities and detector facilities.
For accelerator facilities, international cost sharing has been practiced in the past at CERN, where every member country contributes to the budget in proportion to its economical power.
CERN finances from its budget the construction and the operation of its accelerator facilities. I think the prospects are good that CERN, the model for "true" international cost sharing, will continue to operate in this way also in the future.

Another model of international cost sharing in the construction of an accelerator facility is practiced at present at DESY, where we build HERA with international cooperation. Here the various partners contribute components manufactured in their domestic industries. It is foreseen that the operation of this facility is financed by the host laboratory, i.e. DESY from its budget which comes from the German Federal Government and the Hamburg State Government, the Senate. From my experience with setting up the HERA collaboration I think that prospects are not bad to set up a similar collaboration for the construction of a future accelerator facility, provided some criteria can be met, viz:

- the host country provides the major part of the necessary funds
- the host country will finance the operation of the facility
- free access to the facility is granted following the ICFA-recommendations to scientists from all countries, which means also countries which do not contribute to the construction
- the participating countries find for their contributions items which are of technological interest for their laboratories and industries
- no (or little) money flow is required.

For detector facilities, international collaboration has a good tradition and the prospects for international collaboration with cost-sharing are very good also in the future.

2. What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?

Answer: (a) International cost sharing for big science facilities has the obvious advantage that it might allow the construction of facilities which individual countries feel they cannot construct alone for financial reasons.
As cost sharing almost automatically means international collaboration, it has the other advantage of bringing together scientists and engineers of several countries for true and peaceful international collaboration. Smaller

countries may also consider it an advantage that through an international collaboration in the construction of the facilities they get a chance to be full partners in front-line science.

(b) International collaboration with cost sharing through the contribution of equipment brings as a disadvantage many additional problems of coordination, organization, and administration. It therefore bears the risk to be less efficient and maybe somewhat more expensive than a form of organization, where a budget is given to one institution.

3. How many high energy physicists are performing research at DESY and how much funding is provided for high energy physics research?

Answer: At DESY, there are at present about 500 physicists performing research in high energy physics. These physicists work in six international collaborations on the PETRA- and DORIS-storage rings. About 70 of them have a DESY contract, about 150 come from German universities and research institutes, and 270 from foreign countries.
As for the funding, I can only provide some figures for Germany and physicists coming from German universities:
The DESY budget in a "normal" year is about 145 MDM (1984 prices). This inlcudes the salaries of about 1000 staff, the operation of the two storage rings DORIS and PETRA and of the synchrotron radiation laboratory and a major part of the operation of the detectors at DORIS and PETRA (foreign groups contribute to the operation of the detectors). It also includes the running costs of the whole laboratory.
In the years 1984-1989, about 600 MDM are added for the construction of HERA, distributed over the years with a profile peaking in 1987. The exact figure will depend on the cost increases over the years of HERA construction.

The DESY budget is provided by the German Federal Government (90 %) and the Hamburg State Government, the Senate, (10 %). For the HERA construction, the Hamburg contribution amounts to 15 %.
The Federal Minister for Research and Technology funds university groups in Germany with 20 MDM per year (10 M for personnel, 10 M for equipment) for high energy physics research, of which 4-5 M per year were given to groups working at DESY in the last years. This share will go up for the years 1987-1990 when the HERA experiments will be set up.
The staff paid out of these funds supplements the university personnel which is paid for by the universities. Here I can give no figure.

4. What would be the best worldwide configuration of high energy physics facilities from the point of view of science? How might this best be determined?

Answer: Most if not all future accelerator facilities for high energy physics will almost certainly be colliders, since the high center of mass energies required can only be achieved with that kind of facility. There are bascially three kind of collisions between high energy particles to be studied with colliders:

hadron-hadron collisions in proton-proton or antiproton colliders, lepton- (anti) lepton collisions in electron-positron colliders, and lepton-hadron collisions in electron (positron) proton colliders. A promising field with the potential for new insights is also the study of collisions between complex nuclei at relativistic energies, to be investigated in nuclear colliders like the RHIC proposed by BNL.

The four kind of colliders address eventually complementary scientific questions, having nevertheless some overlap.
There are strong scientific reasons to have in the next generation at least one collider of each of the four kinds, which allows for its particular reaction a major step forward in the available center of mass energy. At this moment, there are important scientific questions specific to each type of collider. Whether this situation will repeat itself in the next but one generation, is an open question to be answered on scientific grounds, mainly on the basis of the results obtained with the machines now under construction.

5. Should some or all future "big science" facilities be developed on the basis of international cooperation?

Answer: I think that for the development of the big facilities one should always invite international collaboration of one sort or another. This should be done in order to make sure that all the latest scientific and technical know-how enters the design, independent of the possibility for a later collaboration in the construction with cost sharing. For high energy physics facilities this international collaboration in the development stage is widely practiced.

6. What is the trend of international collaboration in high energy physics? Is it increasing, decreasing or remaining relatively constant?

Answer: In high energy physics, international collaboration is certainly increasing. This is well demonstrated by the fact that we build in Hamburg now a large accelerator facility at a national laboratory, DESY, in international collaboration. This is certainly a step forward in international collaboration. Increasing international collaboration is further demonstrated by the way in which the big detectors are being built for the new colliding beam facilities SLC, Tevatron Collider, LEP and HERA by large international teams, which include scientists from both sides of the Atlantic, from Japan, from Eastern Countries like the Sowjet Union and Poland, from the People's Republic of China, from Israel and from other countries.
One of the proposals for a HERA-detector for example is signed by about 200 scientists from nine countries. This type of international collaboration on a large scale is to my mind also a remarkable achievement of high energy physics, besides the exciting scientific results.

7. What factors (a) facilitate or (b) inhibit international cooperation in high energy physics?

Answer: (a) Here are some factors which facilitate international collaboration:
The home institutions in particular the universities, have to be sufficiently generous to their teaching personnel to allow

them freedom in arranging their teaching duties, so that they can actively participate in an experiment far away from their home university. It certainly facilitates international collaboration or working on a large center, if the distance is not too big, so that an easy communication is possible. In Europe we have the big advantage that from almost every country collaborating in DESY or CERN one can communicate between the large facility and the home university on a day to day basis. Funding agencies should certainly appreciate the additional problem which arises with international collaboration where much travel is required. They can facilitate the collaboration by making the necessary travel funds available.
There are more points of this practical nature which I hesitate to list here. The host laboratory can of course help to make the social environment acceptable for the visiting scientists and engineers from the various countries. This also greatly facilitates international collaboration.

(b) There are some administrative problems which inhibit international collaboration like customs regulations, visa problems for people from Eastern Countries or the permission to cross freely the boarder, problems of data connections across boarders and so on. They have been addressed e.g. by the Summit Follow Up Working Group on High Energy Physics and outlined in the Report to the Bonn Conference.

8. Does the rest of the worldwide high energy physics community agree with the U.S. high energy physics community that the Superconducting Super Collider or a similar facility is the highest priority?

Answer: With the technology of today, the highest center of mass energies can be achieved with proton-proton or proton-antiproton colliders like the SSC or similar projects discussed elsewhere, e.g. the LHC in the LEP-tunnel. The success of the CERN proton-antiproton collider gives us confidence that such a machine has a high scientific potential. I think it is correct to say that at this moment, most high energy physicists would agree that a very high energy proton proton or proton-antiproton-collider would have highest priority as a machine of the next generation.
If a technique would show up which allows to collide electrons with positrons at much higher energies than with LEP at CERN this priority might be questioned.
We hope of course that by then the hadron collider is under construction at some place and that the high energy electron-positron collider would be the machine to be built next.

9. What does "world leadership" in high energy physics mean? What particular benefits accrue to the "world leader" versus "number two"?

Why should national policy makers care whether or not the nation is first, second or third in high energy physics research?

Answer: I would prefer to not answer that question. I think that we have learned in the past ten or twenty years to collaborate internationally on the front line facilities in such a way that scientists from all nations involved in this reseach share the credit for its

success. We also have arrived at a situation where front line machines which attract scientists from many countries are located in several regions of the world.
In such a scheme it is obviously inevitable that at a given moment in time the facility in one place has the chance to give best physics. In the long term however, this should average out. National policy m akers should care that their nation takes its share in this world-wide effort to explore the secrets of matter, that the funds they make available are used to build front-line facilities both, accelerators and detectors, and that the scientists of their country get the chance to do excellent research in international collaboration.

10. Are the experiences of international cooperation in high energy physics directly applicable to other fields of science? What lessons may be learned?

Answer: I don't think that one can easily apply the experience made in high energy physics to other fields of science. High energy physics is charactericed by very large collaborations with a large number of scientists. This nearly dictates international collaboration.
I don't know of any other field of science where the teams need to be as large as to make international collaboration of that type a necessity.

V. Soergel

QUESTIONS FOR THE RECORD

G. Brianti

1. *WHAT IS THE FUTURE PROSPECT FOR THE INTERNATIONAL COST-SHARING OF THE NEXT GENERATION OF HIGH ENERGY PHYSICS FACILITIES. BOTH IN TERMS OF CONSTRUCTION AND OPERATION?*

The total cost of high energy physics for a given nation or a group of nations can be divided in two categories :
i) construction and operation of accelerators/colliders and related infrastructure,
ii) construction and operation of experimental detectors.

In general the costs of i) are covered by the Agency responsible for the laboratory, while the costs of ii) are shared in wide international collaborations.

At CERN, the "Agency" is formed by thirteen Member States and the costs i) are shared among them on the basis of an International Convention, which has insured stability and continuity of the Organization for more than thirty years. Recently the LEP experiments at CERN plan to receive ~ 35% of the total cost from foreign countries in the form of actual components.

Either methods could be applied to a new large facility.

2. *WHAT ARE (A) THE ADVANTAGES AND (B) THE DISADVANTAGES OF SHARING THE COST OF BIG SCIENCE FACILITIES ON AN INTERNATIONAL BASIS?*

(a) Advantages

i) The obvious one that, by pooling human resources and financial means, a better and more advanced facility can be built,
ii) The daily "work together" of people with different cultural backgrounds and mentality, which often constitutes an enrichment of the individual participants, their home institutions and through them other scientists and students. It contributes to promote high standards of excellence and allow wider access to frontier research facilities.

(b) Disadvantages

i) The danger that the potentially accrued value of the united facility is lessened by difficulties or hesitations of one or more of the partners.

3. *HOW MANY HIGH ENERGY PHYSICISTS ARE PERFORMING RESEARCH AT CERN AND HOW MUCH FUNDING IS PROVIDED FOR HIGH ENERGY PHYSICS RESEARCH?*

The total number of high energy physicists performing research at CERN is ~ 2700, of which ~ 2200 come from CERN Member States and ~ 500 from non-Member States (~ 200 from USA).

The total CERN budget is 700M Swiss Francs per annum. To this one should add ~ 600M Swiss Francs spent nationally in the CERN Member States.

4. *WHAT WOULD BE THE BEST WORLDWIDE CONFIGURATION OF HIGH ENERGY PHYSICS FACILITIES FROM THE POINT OF VIEW OF SCIENCE? HOW MIGHT THIS BEST BE DETERMINED?*

The best worldwide configuration would be one in which complementarity is achieved in one or more of the following features :
i) energy of particle collisions at constituents'level
ii) types of particle collisions
iii) research aims
iv) dates of initial operation.

Ideally it would be attractive to explore the energy range above Tevatron I at Fermilab, namely the TeV region, by one hadron collider (proton-proton or proron-antiproton) and one electron-positron collider with a reasonable geographical distribution, e.g. one in USA and one in Europe.

However it must be noted that the technologies to realize the two types of installation have not reached to-date the same degree of maturity. While circular hadron colliders would make use of rather well established techniques, the electron-positron linear colliders eagerly await results of the SLC at SLAC in 1986 for 50 GeV on 50 GeV, before an extrapolation to, say, 1 TeV on 1 TeV can be based on solid grounds.

Concerning hadron colliders, the highest cost effectiveness, namely the cost in $ per TeV, would be achieved with the LHC in the CERN LEP Tunnel, because of the existing infrastructure (injectors, tunnel, laboratory facilities)- Globally, the most rational approach would be to review the situation at the end of 1987 after one year of operation of the SLC in the USA and the conclusions of the Working Group on the Scientific and Technological Future of CERN chaired by C. Rubbia.

5. *SHOULD SOME OR ALL FUTURE "BIG SCIENCE" FACILITIES BE DEVELOPED ON THE BASIS OF INTERNATIONAL COOPERATION?*

In high energy physics all big facilities are used internationally. For their construction and operation, it is difficult to make very general statements (see also the answers to other questions).

6. *WHAT IS THE TREND OF INTERNATIONAL COLLABORATION IN HIGH ENERGY PHYSICS? IS IT INCREASING, DECREASING OR REMAINING RELATIVELY CONSTANT?*

By international agreement established in 1954 among thirteen European Countries, all CERN projects have been built internationally. In addition, the trend of international collaboration in high energy physics is a steady increase for what concerns experiments, in particular in the case of large detectors. Examples are L3 at CERN LEP, and indeed all LEP experiments, and CDF at Fermilab. Recently, also the HERA collider at DESY (Germany) has been based on a financially modest but technologically significant international collaboration in the form of actual machine components supplied by foreigh countries.

7. *WHAT FACTORS (A) FACILITITATE OR (B) INHIBIT INTERNATIONAL COLLABORATION IN HIGH ENERGY PHYSICS?*

(a) Factors which facilitate international collaboration:
i) The hope of achieving a better global result
ii) The success already obtained through international collaboration.

(b) Factors inhibiting international collaboration:
i) National pride
ii) Fear of a decreased activity in the local Universities.

8. *DOES THE REST OF THE WORLDWIDE HIGH ENERGY PHYSICS COMMUNITY AGREE WITH THE U.S. HIGH ENERGY PHYSICS COMMUNITY THAT THE SUPERCONDUCTING SUPER COLLIDER OR A SIMILAR FACILITY IS THE HIGHEST PRIORITY?*

The world high energy physics community agrees that progress in this science can only be achieved by enhancing the range of energy available in the TeV region.

At the moment, the only predictable way of achieving this is by building a hadron collider considerably larger than TeV I. However, the answer to question 4 should be borne in mind.

9. *WHAT DOES "WORLD LEADERSHIP" IN HIGH ENERGY PHYSICS MEANS? WHAT PARTICULAR BENEFITS ACCRUE TO THE "WORLD LEADER" VERSUS "NUMBER TWO"? WHY SHOULD NATIONAL POLICY MAKERS CARE WHETHER OR NOT THE NATION IS FIRST, SECOND OR THIRD IN HIGH ENERGY PHYSICS RESEARCH?*

I do not think that the "world leadership" has a real significance for high energy physics, which is an open field where all results are published. However, given its cultural relevance, what is important for a nation or a group of nations is to maintain a support vigourous enough to attract excellent young researchers into the field. In practically all cases, these scientisits will have the opportunity to carry out their research in wide international collaborations, very often on a world basis.

Hence the importance of geographical distribution of facilities, so that fore-front research can be carried out by University teams in more than one nation or region.

10. *ARE THE EXPERIENCES OF INTERNATIONAL COOPERATION IN HIGH ENERGY PHYSICS DIRECTLY APPLICABLE TO OTHER FIELDS OF SCIENCE? WHAT LESSONS MAY BE LEARNED?*

Certainly the experiences of international cooperation in high energy physics can be applied in other fields of fundamental research. In my opinion the advantages of international collaboration go much beyond the sharing of cost. It fosters scientific excellence and enriches the participants by the exchange of different experiences and by the daily comparison of more varied cultural backgrounds.

POST-HEARING QUESTIONS AND ANSWERS

RELATING TO THE

APRIL 25, 1985, HEARING

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

WITNESS: DR. JAMES E. LEISS

51-563 O - 86 - 4

Question 1: What is the future prospect for the international cost-sharing of the next generation of high energy physics facilities, both in terms of construction and operation?

Answer: It is too early to give a definitive prediction of the prospects for international cost sharing in the next generation of high energy physics facilities. With regard to the Superconducting Super Collider, SSC, project which is being studied in the U.S., we are actively pursuing opportunities for international cooperation and cost sharing. We are, for example, pursuing this through the Economic Summit process. Dr. Trivelpiece, the U.S. representative and Chairman of the High Energy Physics Working Group, recently sent a letter to his Summit colleagues inviting participation of scientists from their countries in the SSC effort. By this process, we hope to develop grassroots interest in SSC among foreign scientists as a step toward more substantial and formal participation. The Western European community is heavily committed through the remainder of this decade to its own major efforts to build two one billion dollar class high energy physics facilities, the Large Electron-Positron facility, LEP, at CERN and the Hadron-Elektron-Ring-Anlage facility, HERA, at DESY. Although they are unlikely to be able to contribute to SSC construction, I believe that there will be significant European collaboration in detector fabrication for the SSC. Also, I am optimistic about the possibility of substantial collaboration and cost sharing with the Japanese, although we don't have any specific indications at this time.

With regard to international sharing in the operation costs of facilities, we believe that charges for use of accelerators would have a negative impact on international cooperation on a global basis. Clearly, if we were to impose a use charge on foreign users, they would reciprocate by imposing such

charges on the U.S. for use of their facilities. Such a condition would tend to discourage international collaboration. Furthermore, there would be no long-term net gain to the U.S. from such a procedure since U.S. physicists currently have their proposals accepted at foreign high energy physics facilities on the basis of their scientific merit with no charge for beam time.

In summary, we recognize the importance of international collaboration and cost sharing in the SSC and are actively exploring and pursuing opportunities and working to develop appropriate mechanisms. As indicated, the prospects of cost sharing in construction are uncertain, while the prospects for cost sharing in major detector fabrication are very promising.

Question 2: What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?

Answer: The primary advantage of international cost sharing in the cost of big science facilities is that it may lessen the financial burden of the host nation. On a long-term basis, the integrated costs to each region may be about the same for a given scope of the world program, assuming that the current balance among regions remains about the same as at present. In addition, once international agreements are achieved, this might lead to the advantage of more stable long-range funding commitments for high energy physics.

The sharing in the cost of large facilities requires the negotiation of formal international agreements and procedures. This process is uncertain, cumbersome, and time consuming. Such a process could cause delays in securing approval for starting projects and also impose complexities and constraints on the implementation and management of the projects. The delays and constraints would result in inefficiences and higher overall costs for the world program. There are also many logistical and administrative problems associated with major international activities, including a multiplicity of formal approvals and other problems such as visa issues and export regulations. Satisfactory mechanisms to deal with these issues do not exist today. Discussions are under way to improve some of these situations through the Economic Summit process.

Question 3: What would be the best worldwide configuration of high energy physics facilities from the point of view of science? How might this best be determined?

Answer: The best worldwide configuration for high energy physics facilities would be one that permits effective exploration of important, unexplored physics domains with no unnecessary duplication of capabilities. Clearly the major types of frontier capabilities as envisioned today are high energy electron-positron colliders, proton-proton/proton-antiproton colliders, and electron-proton colliders at the energy frontier, as well as fixed target capabilities with various types of secondary beams. As the worldwide high energy physics program is evolving today, Western Europe will have the lead role in the early 1990's in electron-positron colliders with the Large Electron-Positron, LEP, facility and in electron-proton colliders with the Hadron-Elektron-Ring-Anlage, HERA, facility, while the U.S. will have the lead in proton-antiproton colliders with the Tevatron I facility and in fixed-target physics with the Tevatron II facilities until the Soviet UNK 3 TeV on 3 TeV hadron collider comes into operation. At this time, there is consensus that the next step beyond these facilities should be a high luminosity proton-proton collider able to explore in the TeV mass scale. The Superconducting Super Collider, SSC, being studied in the U.S. is the leading candidate for this capability.

The characteristics of the best configuration of high energy physics facilities at any given time have to be determined from scientific needs, with worldwide consensus and coordination of plans for new facilities. The International Committee for Future Accelerators, ICFA, and the Economic Summit process provide two special forums for discussion of plans on a worldwide basis and for development of mechanisms for improved international collaboration in high energy physics. In addition, there is extensive communication between high energy physicists of all regions, and it is in the best self interest of each region to achieve unique frontier capabilities in each region rather than redundancy.

Question 4: Should some or all future "big science" facilities be developed on the basis of international cooperation?

Answer: There is a long history of extensive international communication and cooperation in high energy physics, including the planning for new facilties. It has been mutually agreed by the participants in the High Energy Physics Working Group of the Economic Summit Process that the required new and advanced facilities can be built and operated within broadly constant worldwide budgets (with some fluctuations during years of peak capital expenditure), provided that there is no unnecessary duplication. This implies planning on an inter-regional basis to ensure complementarity and cost effectiveness. Further concentration of facilities is inevitable; however, the Working Group is convinced that more than one region working effectively in high energy physics is essential to the health of the science in the period of the study.

Each case should be judged on its own merits in a worldwide context. On the other hand, I think it would be wrong to make a generalized pronouncement that all large future facilities should be developed on the basis of international cooperation.

Question 5: What is the trend of international collaboration in high energy physics? Is it increasing, decreasing or remaining relatively constant?

Answer: International collaboration in high energy physics is very extensive but is also clearly increasing. During the past two decades, we have seen a trend from a mode which primarily involved participation in international meetings and conferences and exchange of individual scientists, to one involving participation in joint experiments and extensive use of each other's facilities on a long-term reciprocal basis and more recently, to joint participation and cost sharing in the design, fabrication, and use of major detectors. For example, there is strong participation by Japanese and Italian scientists in the Colliding Detector at Fermilab, CDF, including a total of about $15 million in cost sharing (nearly 30 percent of the cost of CDF). U.S. scientists are participating to some extent in all four major detectors at the Large Electron-Positron, LEP, facility and one LEP experiment is led by a U.S. scientist. U.S. scientists have indicated their interest in participation in Hadron-Elektron-Ring-Anlage, HERA, experiments. One major experiment on the TRISTAN facility being built in Japan is jointly funded by the U.S. and Japan.

As the cost of major facilities continues to increase, it is clearly essential to avoid unnecessary duplication of facilities and to seek means to reduce the fiscal impact of the large facilities. There is serious pursuit of discussions to establish mechanisms for broader participation. The Economic Summit process is one of these.

Question 6: What attributes of high energy physics make international cooperation easy to achieve?

Answer: High energy physics has a long tradition of international collaboration and cooperation. The many years of working together, which have established successful modes of collaboration and a framework for dialogue, provide a basis of mutual trust and understanding for continued cooperation.

High energy physics is an area where there is strong and widespread interest by all highly developed countries. As an area of very basic research with no immediate military or industrial applications, it is an area where competing regions may freely and openly work together.

Another major attribute of high energy physics which facilitates international collaboration is the concentration of the experimental research at a few large facilities. With only a few major world centers (Fermilab, Brookhaven National Laboratory and Stanford Linear Accelerator Center in the U.S.; CERN and DESY in Western Europe; KEK in Japan; and Serpukov and Novosibirsk in the Soviet Union) and with a cohesive set of physics goals and mutual interests, it is relatively easy for the leaders of the field to focus on the issues and work together to develop mechanisms for cooperation, coordinate planning of facilities, and reach consensus, provided the proposed cooperation results in mutual benefit to all the participants.

Question: Does the field have attributes that make international cooperation difficult?

Answer: The primary impedances to international collaboration in high energy physics seem to lie in the domain of logistical and administrative (visas, foreign travel restrictions, export licensing, etc.) issues rather than in the inherent attributes of the field.

Question 7: Has there been an overinvestment or underinvestment in high energy physics relative to other subfields of physics or other disciplines? How can the appropriate levels of investment in different subfields on disciplines best be determined?

Answer: I believe the best way is to look at the individual programs and assess the importance and excellence of the scientific results of that program, the importance of the program to the nation's overall scientific effort, and the needs a particular program has to remain excellent, productive, and world competitve. I do not feel qualified to try to give an assessment of what is going on in subfields of physics other than high energy physics or nuclear physics, or in other disciplines. I will, therefore, focus my response on the state of high energy physics.

High energy physics is a field in which effectiveness and productivity are critically dependent on the capability of its experimental facilities. A successful high energy physics program demands the availability of facilities capable of forefront research in the important, unexplored physics domains. These facilities are large, complex, and costly. I believe that the U.S. today has a world-competitive high energy physics program. It is also clear that to remain a world-class program further substantial investments in high energy physics facilities are essential. Is the investment in high energy physics out of line with the investment in other science programs? I really don't know how to make such a comparison, but can only state that the present investment in high energy physics has given us a productive, world-class program which has produced many payoffs in scientific discoveries, technological benefits to the nation, and international prestige. A substantially smaller investment would result in a second-class program. An increased investment can be justified and could be profitably utilized.

Question 8: What factors either (a) facilitate or (b) inhibit international cooperation in high energy physics?

Answer: The major factors which facilitate international collaboration in high energy physics are the long history of effective collaboration and cooperation in high energy physics and the concentration of the program on a few large facilities. The large cost of forefront facilities encourages joint use and coordinated planning for the construction of new unique facilities. This need has been recognized by the formal agreement between all major participants in high energy physics that facilities in each region are available to scientists of all regions on the basis of the scientifc merit of their proposal without regard to nationality and without charge for beam time.

The major inhibiting factors to joint funding of facilities are the logistic and administrative difficulties I discussed earlier. In addition, the requirements for international agreements, which move slowly and frequently impose delays and operational constraints on programs, could result in inefficiences and larger overall costs for the world program.

Question 9: Will spending of national funds on international facilities be to the detriment of national laboratories? What is the appropriate level of funding or national research efforts versus international efforts and how should these levels be determined?

Answer: Within a given budget level for the national program there is a competition for funds between efforts related to national facilities and those related to foreign or international facilities. Clearly, if the overall program includes substantial efforts related to international facilities, national facilities will not receive as much funding as they would in an exclusively national program. This can be a detriment to individual national laboratories.

From a more global point of view, each nation must strive to achieve a balanced, comprehensive program with investigations in important physics domains. The costs of facilities and fiscal restraint simply do not permit each nation to have every kind of facility. Use of foreign facilities with unique capabilities not available in the U.S. and participation in the development of international facilities are essential to a well balanced program of research and are the most cost-effective ways to proceed.

There is no simple general answer to the appropriate balance between funding of national versus international efforts. It is a dynamic situation. Each year it is necessary to look at commitments, physics needs, facility capabilities, and the interests of scientists to determine the appropriate balance within available resources. It is essential to have a base of facilities with forefront research capabilities in the national program in order to sustain a world-competitive program. The national facilities must be funded adequately to permit them to operate at a productive, cost-effective level.

Question 10: What does "world leadership" in high energy physics mean? What particular benefits accrue to the "world leader" versus "number two"?

Answer: The concept of world leadership in high energy physics refers to the capability to do forefront research and produce a reasonable share of the truly significant results on a worldwide basis. What is referenced is a world leading or world-competitive position, not one of dominance.

The benefits of a competitive, world-leading program are that the U.S. physicists and the nation share in significant discoveries and excitement of this exploratory field of basic research and receive worldwide recognition and international prestige for scientific and technological leadership. Being able to work at the forefront and make pioneering discoveries provides a strong incentive and drive to the nation's high energy physicists and helps attract the top quality people who are essential to sustain excellence in this highly challenging and demanding program.

The investment required for a high energy physics program is large in terms of funding and manpower resources. This stems from the inherent characteristics of the facilities required for forefront exploration. A program with non-forefront facilities or with facilities which come on late costs as much as a competitive, world-leading program but does not make forefront discoveries.

Question: Why should national policy makers care whether or not the nation is first, second or third in high energy physics research?

Answer: National policy makers should be concerned about the return on the investment made in high energy physics and about the strength of the nation's science and technology base. High energy physics is an important fundamental science base of the nation's scientific and technological strength. The U.S. should be world competitive and have some share of the forefront facilities in the field. It costs almost as much to be second and there is little credit and much less benefit to the nation.

Question 11: Are the experiences of international cooperation in high energy physics directly applicable to other fields of science? What lessons may be learned?

Answer: High energy physics has clearly been a pioneer in establishing mechanisms for effective international cooperation and collaboration. Clearly the patterns and mechanisms developed in high energy physics could be beneficial to other fields, particularly those requiring large facilities. Perhaps the biggest lesson to be learned is that successful international cooperation requires mutual interest and benefit. We have learned that it is essential to develop a basis of dialogue and interaction before attempting any significant collaboration or cost-sharing efforts. International cooperative efforts have had the mutual and beneficial effect of providing each region with access to unique research opportunities which it could not afford to provide locally.

QUESTIONS AND ANSWERS FOR THE RECORD

Professor Jean Sacton

Preamble: Because of the strong relationship between some of the questions, I would appreciate that these answers be looked at as a whole.

This document summarizes my personal views and should not be considered as representing the views of ECFA.

Some of these questions are worthy of much longer discussion than the few enclosed comments.

1. **What is the future prospect for the international cost-sharing of the next generation of high energy physics facilities, both in terms of construction and operation?**

The next generation of high energy physics facilities will be expensive and therefore unnecessary duplication should be avoided. However, access to a variety of machines (such as hadron-hadron, electron-positron or electron-proton colliders) will remain a must for ensuring the success of our field. It is therefore expected that high energy physics facilities will continue to exist in various regions. In operating these facilities, the regions will have the obligation to open them to competent physicists from all over the world, the access being guaranteed on the sole consideration of the scientific value of the proposed experiments and their technical and financial feasibility. As is presently the case for most of the big high energy physics laboratories, there should be no or minimal participation of the outside users to the operational costs.

As far as the funding of the construction of accelerators is concerned, Europe has experienced two different models:

(a) CERN, which is an international organization, is funded by its various Member-States according to well defined quotas. The fund is at the disposal of the organization to develop an agreed programme of accelerator construction and exploitation.

(b) DESY, a national laboratory, has recently started the construction of the HERA ep collider. This machine will be funded mainly by the German Authorities with a participation from other countries supplying either homemade machine components or manpower. The nature and the level of this participation is determined on the basis of bilateral agreements between each country and Germany.

Model (a), proposed in the Fifties, has proved to be successful in Europe but would be probably much more difficult to implement nowadays at an interregional level. Model (b) seems promising but its success has still to be assessed.

The exchange of specialized personnel during the R&D phase preceding future accelerator construction should also be viewed in the future as an essential contribution to the project.

In the construction of large facilities, the active involvement of industry, both from the host region and from the other participant countries, should be encouraged even during the R&D phase. This participation should be organized, however, with great care in view of the widely different local situations.

It is worth mentioning that general purpose detectors in use at colliding beam facilities can be considered as part of the machine. Cost sharing in detector construction is already a current practice.

2. **What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?**

Cost sharing of "big science" facilities on an international basis should contribute to avoiding unnecessary duplication, it should permit the realization of ambitious projects which otherwise would remain fiction. Such unique facilities would unavoidably drain top skilled scientists, engineers and technicians from all parts of the world and contribute to the creation of centres of excellence. However, various kinds of management difficulties, inherent to big international enterprises, could lead to a rapid decrease in efficiency (lack of autonomy, lack of flexibility). In the long term the danger is real for a loss of competition spirit and creativity which could, nevertheless be overcome if various local programmes of high quality are run in parallel. These programmes would be essential for the training of those people who will later be working at the central facilities; they should ensure the indispensable links with the universities and technical schools and should contribute to spread equitably the spin-offs (intellectual and technical) to be expected from the central facilities.

In this discussion, the industrial participation should be looked at carefully. A continuous search for compromises in order to minimize discrimination and injustice could be paralyzing. Nevertheless, balanced solutions will have to be found when choosing between cost effectiveness and just return, standardization and originality, ...

3. **How many high energy physicists are performing research in Europe and how much funding is provided for high energy physics research?**

Two surveys of the high energy physics community in Europe have been made by ECFA in 1978 and 1983, respectively. It was found that over this period both the size and the composition (experimentalists, theoreticians, Ph.D. students, ...) of the community were quite stable. The figures for 1983 are as follows:

Experiment	Theory
~ 2000	~ 1100
(which ~ 25% are Ph.D. students)	

Regarding the funding provided for high energy physics in 1983, the following figures were given to me by Mr. C. Roche who is compiling this information for CERN since many years.

Member States contributions to CERN: 700 M Swiss Francs
National Expenditures of all Member States: 600 M Swiss Francs

These figures include salaries and overhead.

4. What would be the best worldwide configuration of high energy physics facilities from the point of view of science? How might this best be determined?

As stated previously (see answer no. 1) various types of super colliding beam machines which could give us access to a new mass scale are presently considered to be the future basic instruments for high energy physics. Some of these machines are based on well understood physics principles (e.g., the hadron-hadron colliders) whilst others are still in the R&D stages (such as the electron linear colliders). However, this is not the only element which prevents us from defining today the best world-wide future configuration of high energy physics facilities. Indeed, the physics results from the present generation of accelerators as well as further theoretical developments will be essential inputs to this decision making process. From the economical viewpoint, complementarity and cost effectiveness should be taken into account seriously in defining our global strategy.

Please allow for some flexibility to accommodate the unexpected.

5. Should some or all future "big science" facilities be developed on the basis of international cooperation?

International cooperation in the development of "big science" facilities should be driven by both scientific and economic motivations. It should not be improvised, but it should be prepared long beforehand and planned very carefully. In high energy physics it has started since a long time and has developed progressively to the present level. There is no doubt that this cooperation has proved to be extremely beneficial to our field. Some national programmes had, however, to be abandoned but the expertise, the know-how were at that time already well distributed among the various participating countries allowing for an efficient exploitation of the central facilities.

6. What is the trend of international collaboration in high energy physics? Is it increasing, decreasing or remaining relatively constant?

Undoubtedly the trend of international collaboration in high energy physics is increasing primarily as a result of the increased complexity and cost of the apparatus needed (accelerators and detectors). The efficient exploitation of sophisticated facilities imposes the pooling of resources: manpower, material and money. Also the availability of more and more efficient computer links and networks makes it easier to exploit central facilities remotely, even by small groups.

7. What factors (a) facilitate or (b) inhibit international cooperation in high energy physics?

As stated above, international collaboration in high energy physics has been driven by the necessity of pooling resources to build and exploit the tools indispensable to develop our field. The resulting big facilities constitute a pole of attraction for all those wishing to share the intellectual skill and the first class technological expertise which are concentrated there. Once such a process is initiated, it keeps up and even develops as a rolling snowball. International cooperation is for us common practice which will surely be facilitated by the recent developments of computer communication networks. The experience of working in such a frame provides also an insight into personnel and organizational matters which is frequently lacking in scientific personnel trained in other disciplines.

Various factors may however contribute to inhibit this collaboration, of which I would like to mention:

i) sociological and administrative obstacles (language problems, admission formalities in the host country, integration of the family -- schools, work permits --, regulations governing the international transfer of scientific equipment, ...)

ii) geographical location of the facilities (distances, communications, possibilities of daily commutation, ...)

iii) lack of traveling funds (European high level of air fares has inflated travel expenditure)

iv) international PTT tariffs and lack of standardization for computer communications.

8. Does the rest of the worldwide high energy physics community agree with the U.S. high energy physics community that the Superconducting Super Collider or a similar facility is the highest priority?

We know that one clear need has emerged from our present studies which will not be met by the accelerators now under construction. This is the requirement to increase the energy range available for high mass particle production. Large hadron colliders, such as the SSC, are privileged candidates in this race. Being based on "classical" concepts, their realization is essentially dependent of our ability to mass produce medium or, more challenging, high field superconducting magnets. Hadrons are composite particles made up of bound quarks and the results obtained from high energy hadron-hadron collisions should be valuably complemented by those from similar studies with structureless particles such as electrons and positrons. Unfortunately, for the time being, technical limitations prevent us to efficiently accelerate electrons up to the needed energies. Large electron linear colliders are presently under study but an intensive R&D program would be required (and should be pushed) to convince the community of the technical feasibility of these machines.

9. **What does "world leadership" in high energy physics mean? What particular benefits accrue to the "world leader" versus "number two"?**

Why should national policy makers care whether or not the nation is first, second or third in high energy physics research?

At the occasion of a discussion of the future prospect for interregional collaboration, I will refrain from polemizing about the meaning of "world leadership".

10. **Are the experiences of international cooperation in high energy physics directly applicable to other fields of science? What lessons may be learned?**

International cooperation in high energy physics is going on since a long time in detector design, construction, testing and exploitation. Also the collaborative exploitation of various accelerators is a common practice. At variance, high energy physicists have still little experience in cost sharing and cooperating in the construction of accelerators (apart from expertise exchange) and it might be that this would prove to be a more delicate exercise. Usually a big detector is built, run and exploited in common by the same partners. In the case of the accelerator (I am referring to the case of HERA at DESY), various components built in local industries will be assembled in the host laboratory. The machine will be run under the responsibility of the host laboratory for the benefit of a large variety of users. Moreover, whilst a detector can be considered as a combination of various (more or less) independent modules, an accelerator works as a whole, most of its components being fully integrated in the complete system. In case of difficulty, the definition of responsibility might become a delicate exercise.

This example shows that in our own field, different modes of cooperation exist. One should thus be cautious in directly extrapolating our experiences to other fields of science without a careful analysis of the specific needs.

Written Response to HST Questions
Concerning International Cooperation in
High Energy Physics

B. D. McDaniel

June 20, 1985

1. What is the future prospect for the international cost-sharing of the next generation of high energy physics facilities, both in terms of construction and operation?

While there is generally good international collaboration in the use of high energy physics experimental facilities and the CERN laboratory has been established as an international collaboration of the European region, the prospects of international collaboration between regions for sharing construction and operational costs are not very optimistic for the near future. Both Europe and Japan are very heavily committed at the present time to construction programs. At their current level of funding it will be several years before significant funds will become available for these countries to support any major program of international collaboration on construction. It should be pointed out that the current level of support for high energy physics in Europe when measured in terms of the gross national product is already about twice that of the United States. If one is to expect significant contributions to a new major collaborative program, it is difficult to see how this could be accomplished without a joint decision by our President and the foreign chiefs of government with substantial increases in resources becoming available from foreign sources for this field of activity.

With regard to the question of collaboration in support of operating costs the ICFA agreements, which are uniformly accepted by all regions, state that the regional laboratory facilities should be made available to all investigators without cost, subject only to the scientific evaluation of the proposal. The statement of this principle is given in full in Attachment II of my written testimony submitted on April 25, 1985. The agreement on this principle was in itself a major achievement of the ICFA group and a major step in international cooperation. To now ask for cooperation in supporting operating expenses would be a backward step. In the full statement, there is recognition that there may develop some unbalance in the international program and that special considerations may be given to

compensate for this unbalance. While some method of sharing operating costs could be developed, except in a condition of major unbalance, it would appear that the organizational efforts required to work out a detailed sharing scheme would exceed the value.

In the case of the regional facility of CERN, we have an example of international cooperation among the CERN member states both in the construction and operation of accelerators. In principle this model could be extrapolated to a world-wide basis. There are, however, several factors which affect the desirability of making such an effort. It has become recognized that the field needs complementary accelerators, e.g., hadron-hadron collider, electron-positron collider, and electron-proton collider. While in principle these might all be constructed under a common management scheme and perhaps located in different regions, the economic advantage of such an arrangement is negligible except in the sense of "load leveling" for the countries involved. Such a centralized organizational arrangement might also reduce the regional competitive incentive which plays such an important role in the advancement of the field. It is anticipated that many years would be required to establish such a broad international cooperation and would, in the meantime, delay progress in the field.

2. What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?

a. Advantages: If one starts from the premise that more than one type of facility is required and that redundant facilities will not be built in any case, the principal advantage of sharing the cost of facilities on an international basis is to smooth out the variation of financial load on a given country while construction is being carried on in that country. As long as there is no redundancy and the same world-wide program is to be carried out, averaged over a long period of time, there will be no net saving for any individual region of the world. Of course if the burden can be shared among other countries which are not currently supporting such programs, this would lessen the burden on the others.

b. Disadvantages: Considering first the sharing of construction costs, one of the most difficult aspects is the organizational problem. In order to initiate such an effort many years of negotiation at the highest governmental levels will be involved. Such negotiations are made difficult because of nationalistic pride and the nature of the long term commitments which are necessary. When new initiatives are required, the flexibility in dealing with such matters is reduced because of the necessity of obtaining agreement among all the members. One way to avoid such delaying difficulties is for one nation to commit itself to a major project and then to seek supplementary support from other nations or regions. In such a plan, of course, the lead nation suffers from a weak negotiating position.

Considering the sharing of operational costs, if the facilities are relatively well balanced between regions, there is no net advantage of sharing operational costs. The difficulties in budget management will be much increased and will require considerable negotiation to provide a satisfactory operating mode. Furthermore, if qualified scientists from non-contributing poorer nations are excluded from the use of the facilities, the quality of the science will suffer.

3. What would be the best worldwide configuration of high energy physics facilities from the point of view of science? How might this best be determined?

Speaking in general terms, one would avoid construction of redundant facilities and schedule complementary front-line facilities with one major facility in each major region, perhaps two or three in all. Speaking more specifically in the context of the current situation, the phasing is appropriate for a major hadron collider such as the SSC to be built in the U.S. By the mid 1990's Europe will have recently completed two major facilities (LEP and HERA) while the opportunities in the U.S. will be seriously diminished. It is appropriate therefore that the next major facility be the SSC hadron collider in the U.S. To have the facility available at that time will require starting of construction at a very early date. The next machine after that might be an e^+e^- collider perhaps to be built in Europe or Japan after adequate research and development has been performed to make this possible.

While it might appear that a closely coordinated plan for world-wide physics would be the best way to proceed, this has the danger of too close regulation of activities and the hazard of excluding innovative ideas. By having the possibility of independent initiatives, new ideas may develop and be executed and lead to better science opportunities. It seems that perhaps the best mode is to maintain close communication with the several active regions in an attempt to avoid redundancy and plan an international strategy without enforced discipline. At the present time, there are three major regions of activity and there are at least three major types of facilities required to address the questions of high energy physics. It is reasonable that each of the regions provide one of these facilities. From time to time, over many years, this configuration will of course change. A strong and active forum for such discussion and planning should be provided. At the present time, ICFA could in principle provide such a forum; however, to really do its job, it needs to be strengthened and to be recognized as an important body at high governmental levels by the participating nations.

4. Should some or all future "big science" facilities be developed on the basis of international cooperation?

Perhaps the day will come when one particular facility of enormous magnitude will be required in order to make further advancement in a field of science. When such a facility is recognized as being uniquely required and of such magnitude that national or regional funding sources are clearly inadequate to accomplish the goal, then the effort should be organized on an international basis. As long as complementary attacks on the goals of the field are possible and can be accomplished within the financial resources of national or regional nature, it seems desirable to coordinate the activities between regions but maintain independent efforts. This will enhance the competitiveness of the field, a force which drives the science. Of course, redundancy in the construction of very large facilities should be avoided.

5. What is the trend of international collaboration in high energy physics? Is it increasing, decreasing or remaining relatively constant.

   Collaboration seems to be increasing as evidenced by the participation of several nations in the construction efforts for the HERA machine at DESY. Though in the past there have been a few efforts by various countries to supply particular elements of hardware to an accelerator facility, the contributions being made to HERA are on a much larger scale than such previous efforts. In recent years there have of course been large contributions by various national collaborators to the construction of large detection facilities and this activity has increased as these facilities have become larger.

6. What attributes of high energy physics make international cooperation easy to achieve or difficult to achieve?

   Because of the nature of a pure science there is no pressure to maintain secrecy or to struggle for any financial gain. It is a highly competitive field, but the interest in pure scientific achievement dominates and makes it easy to establish collaborations.

   One significant deterrent to scientific collaboration is the complication and delay that may arise in a multinational effort. The difficulties include communication and travel problems, but also, in any large effort, include negotiations at high governmental levels. Such negotiations are likely to lead to large delays in the program. There is a major factor which makes collaboration difficult and it is the nationalistic pride and desire to be scientifically dominant in the field. Such attitudes of course are reinforced in many cases by the national political interests.

7. Has there been an overinvestment or underinvestment in high energy physics relative to other subfields of physics or other disciplines? How can the appropriate levels of investment in different subfields or disciplines best be determined?

   I believe there is no quantitative way to answer this question because it is so subjective. There are, however, some important

principles. Because of its intellectual nature, there is little "pay off" for engaging in high energy physics unless occasionally one is able to make a frontier discovery, thus if one is to compete in this activity one should do so at a productive level. The competitive aspect ensures and stimulates a high quality of activity in the field. It seems clear that a reasonable balance should be maintained between the various fields of science since they interact and mutually strengthen each other. The measure of whether there is overinvestment or underinvestment in high energy physics seems to revolve around the question of whether we are able to maintain a competitive position in the field. I believe that we are now just barely maintaining a competitive position in high energy physics and that we must make sure that we do not drop out of the competition.

8. What factors either (a) facilitate or (b) inhibit international cooperation in high energy physics?

   Because it is a field of pure science without military or commercial applications, open communication exists. This facilitates cooperation. The state of international political relations can either facilitate or inhibit the cooperation. This has been clearly shown in recent years in the case of collaboration with the USSR. The availability of complementary capabilities or resources may facilitate the cooperation. Bureaucratic import and immigration controls may needlessly and severely inhibit international cooperation. Cost of travel is of course also an inhibition.

9. Will spending of national funds on international facilities be to the detriment of national laboratories? What is the appropriate level of funding or national research efforts versus international efforts and how should these efforts be determined?

   If, in the long run, an appropriate "balance of trade" is not maintained in the field, the national laboratories will suffer. The instantaneous ratio of foreign to domestic spending may not be greatly important provided a strong and competitive domestic facility program is maintained. I believe that a very competitive domestic facility program is essential to maintaining the long term viability of the national effort in the field. I would estimate that the present ratio of spending on foreign efforts is at a reasonable level and should be

maintained provided the reciprocal balance by other nations is also provided. HEPAP appears to be the appropriate organization to make recommendations to the Department of Energy on this subject.

10. What does "world leadership" in high energy physics mean? What particular benefits accrue to the "world leader" versus "number two"? Why should national policy makers care whether or not the nation is first, second, or third in high energy physics research?

There are always a few select and very important frontier discoveries to be made at any given time. The laboratory and nation which provides the facilities for such discoveries is largely given the credit for such discoveries. World leadership means then that a particular laboratory or nation leads the world in providing the facilities for such discoveries. The importance of such a lead is a matter of national prestige, both to members of the field and to the government. For many years the field of high energy physics has been recognized by many of the governments of the world as a field of high intellectual pursuit; leadership in this field contributes to the broader national prestige. The reason for this is quite clear. We have seen throughout the history of mankind that knowledge acquired through basic research has ultimately always yielded results out of proportion to the investment. We have observed this with regard to electromagnetism, atomic physics, nuclear physics, condensed matter physics, and in many other fields. In high energy physics one of the difficulties with the number two or three position is that if a nation is consistently in this position, it means that it does not contribute to the cutting edge of the field. The payoff is in being competitive. Being number two by turns is not so bad, but being always in such a position will inhibit the domestic interest in the field. Loss of such an interest will be to detriment of the overall prestige of the nation and will lead to the eventual decline of the field.

11. Are the experiences of international cooperation in high energy physics directly applicable to other fields of science? What lessons may be learned.

It would appear that these experiences might be directly applicable to certain fields, e.g., radio astronomy, space telescopes and space labs, and other fields where highly sophisticated and expensive facilities are required in an intellectual pursuit and which at the same time are not directly and heavily involved in application and commercial enterprise. However, as in high energy physics, it is important that there be a good "balance of trade" in so far as domestic versus foreign use is concerned in order to maintain a high interest in the field.

APPENDIX 2

Discussants' Questions and Answers for the Record

QUESTIONS AND ANSWERS FOR THE RECORD

Dr. Leon M. Lederman

1. **What is the future prospect for the international cost-sharing of the next generation of high energy physics facilities, both in terms of construction and operation?**

   Here the new ground is in construction of new facilities and their operation. There is very little question but that cost sharing in the construction of large detectors will indeed take place. The substantial players are Western Europe, Japan and collectively, "others" by which I mean Canada, Mexico, Brazil, Argentina, China, Taiwan, Korea, Singapore, India, etc. In this latter category I list nations that have substantial scientific infrastructure and some activity in high energy physics. For example, all of these have some activity at the Fermi National Accelerator Laboratory.

   I believe it is quite feasible and even likely that there can be substantial involvement on the part of Japan, Western Europe and the others if there is wisdom on the part of the U.S. in setting an appropriate strategy. This must be based upon the separate sensitivities of each of the individual regions or countries and upon a recognition of mutual advantages. Some very subjective comments follow.

   Western Europe is in the midst of a major building program with LEP, HERA and associated detectors. We estimate the total cost at about $2 billion. These projects should be complete by about 1990 and, in principle, Europe could then contribute hardware for the SSC at the level of, say, $100 million per year for four years or so. This would represent about a third of the annual expenditure for capital improvement over the previous six years. The contribution would of course be in components for the accelerator and detectors made in Europe and delivered to the SSC project. (In these estimates we include labor costs which are traditionally "understood" in European accounting). Why would this happen? If SSC, in 1986, looks like it will go unilaterally and produce a completed machine by 1994-5, it is difficult to justify a European alternative, e.g., LHC, i.e., a smaller machine with much less scientific potential for the LEP tunnel. If, in 1986-87, the U.S., with SSC looking good politically, offered to share scientific management with Europe, it is my personal opinion that enough scientists would support this and, surely, the European governments would welcome this. More or less, the same comments apply to Japan although there is more sensitivity there to pressure. On the other hand, Japanese industry seems extremely eager to share in the technological spin-offs and would be a strong positive contributing factor.

Canada, a very active country in HEP, would follow if SSC now looked like the focus of the next step in HEP. Each of the other countries has individual problems, but the lure of an experimental counter, where young scientists can be trained in the practice of large science with its associated technologies, would be very strong. Whereas some of these countries are exploding in technological manufacture, others are burdened by large debts but much can change in ten years. The importance of advanced education and a scientific base to gradually make the transition from a high-tech labor pool is widely recognized. The SSC in the U.S. can easily be visualized as a world center of research and the very nature of the objective: abstract, basic knowledge, would do much to make this practical.

When it comes to cost-sharing in the construction of the facility and its detectors, we always mean that the contribution will be in manufactured and non-manufactured materials, rather than in transfer of funds.

2. **What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?**

In the scenario outlined above, one could expect a reduction of cost to the U.S. taxpayer of the order of 10-30% where the upper limit is probably too optimistic. Thus, for example, if the overall total project cost, including detectors, is \$4 billion, one could perhaps expect, say, \$600 million to be contributed, a substantial sum!

Additional advantage comes from the availability of technical experts, an exceedingly rare commodity. Characteristic practice in the U.S. results in a very large workload for a small number of available experts. Europe generally has a much greater depth in their coverage of design, construction and operating tasks by key people.

The disadvantage comes from three sources: (1) increased bureaucratic problems, e.g., treaties, formal agreements, protocols all in a climate of increasing controls on technology transfer, etc.; (2) increased difficulty in decision making that will come from shared management responsibilities; (3) decisions that arise from how industry profit from the advanced technology tasks associated with new accelerators. Should these be shared? Should all countries involved be permitted to bid? The U.S. must clearly decide whether it wants to keep the industrial action to itself or not.

3. **What would be the best worldwide configuration of high energy physics facilities from the point of view of science? How might this best be determined?**

Here is a 1985 Snapshot:

	Operating	Under Construction	Under Design	Advanced Concepts
U.S.	AGS			
	TeV II 800 GeV	TeV I (2 TeV $\bar{p}p$)	SSC	
	CESR, PEP, SPEAR	SLC e^+e^-		
	Sp$\bar{p}$S	LEP e^+e^-		High Gradient
W.Europe	SpS	HERA		Linear Devices
	PETRA			(Lasers, etc.)
	DORIS			
Japan	--	TRISTAN		
USSR	--	UNK I (600 GeV)		

In 1990, the Configuration could be:

	TeV I			
U.S.	TeV II (1000 GeV)	SSC (US)		
	SLC			
	CESR			
	LEP I	LEP II (100x100) e^+e^-		
W.Europe	HERA		Lin. Coll. e^+e^-	?
	S$\bar{p}$ps?		(5 TeV x 5 TeV)	
Japan	TRISTAN			
USSR	UNK I	UNK II		
		(3 TeV x 3 TeV $\bar{p}p$)		

In 1995, an Optimum Configuration might be:

	SSC			
U.S.	TeV II ?		Lin. Coll. pp?	?
	SLC ?			
	LEP II	Lin. Coll. e^+e^-		
Europe	HERA			
	UNK II			

4. **Should some or all future "big science" facilities be developed on the basis of international cooperation?**

My response is that there are three possible modes for international collaboration:

A. Present mode: Country or region builds facility, all regions are welcome to use it.

B. "HERA" mode: Country or region takes leadership in building facility but invites international participation. Thus, the Canadians, Italians and Dutch are bringing parts to HERA.

C. Full scale collaboration under international management, treaties, etc.

Mode A: Optimizes efficiency, technology transfer advantage, scientific prestige but maximizes cost to the host nation and reduces access to world-wide science and engineering talent and ideas.

Mode B: Reduced cost to host (10-20%?), but retains fair efficiency, technology transfer, prestige, etc.

Mode C: Minimizes cost to host and maximizes access to talent at the expense of increased bureaucratic inefficiency, delays, instability (eg., UK and CERN). The <u>total</u> cost of the project will clearly increase from A to C.

I believe we must treat "big science" i.e. central, shared facility, on a case-by-case basis. Mode B would be the ideal arrangement especially since it can be tuned towards A or C. We must be aware of the fact that big science, excluding space, is still only a small part of our $8-10 billion basic research budget; a nation or region with confidence in its own future may very well want to forge ahead without the obvious complications of international treaties. In this case Mode A, which insures collaboration in the exploitation of facilities, is the mode of choice. This does not imply that Mode C will not have its time. The cost sharing feature will very likely outweigh the increased costs due to management complexity and, at some time, may be the crucial element. The World Laboratory is an "impossible dream" which will someday be realized.

5. **What is the trend of international collaboration in high energy physics? Is it increasing, decreasing or remaining relatively constant?**

This is definitely increasing. Approximately 300 U.S. high energy physicists are now committed to experiments in Europe and Japan. <u>Major</u> roles are being played in the LEP and TRISTAN machines. European and Japanese scientists are very active in the TEVATRON program. HERA is being built by collaboration (see above). ICFA maintains active discussions and workshops on future facilities.

6. **What attributes of high energy physics make international cooperation easy to achieve?**

Does the field have attributes that make international cooperation difficult?

"Practice" is the obvious attribute. High energy physics may be said to have been founded after WWII. But high energy physics is simply a continuation, by a new name, of a concern for the fundamental laws of nature and it can call on a tradition of internationalism that goes back 400 years. Perhaps the scarcity of genius made science ignore national boundaries in search of kindred minds engaged in similar fascinations.

Modern developments which have increasingly required shared facilities of even greater complexity again point to international collaboration. Just as universities in the U.S. resorted to ever larger consortia to manage national facilities, European countries banded together in ~ 1950 to organize CERN. In 1975, all active countries organized themselves into ICFA, International Committee on Future Accelerators. The motivation illustrates the attributes: to plan for the eventuality of a world laboratory. Ten years of meetings resulted in three very good workshops but not even a vestige of agreement. This illustrates the dark side of Mode C (#4).

I do not believe the field of HEP has any specific attributes which make international collaboration difficult, with the exception, common to all sciences, that the practitioners are usually professors who must spend some time on campus with their students.

7. **Has there been an overinvestment or underinvestment in high energy physics relative to other subfields of physics or other disciplines? How can the appropriate levels of investment in different subfields on disciplines best be determined?**

This is difficult. All subfields of physics are suffering from underinvestment. It would require the wisdom of Solomon to examine each field with a list of Criteria in mind. These criteria would include scientific opportunities, the quality and enthusiasm of new entrants, the influence of the subfield on other subfields, economic and societal implications, long term history of the field as an indicator of future achievements, relative costs, etc. Clearly to apply this would be a prodigious labor. However, one could put weighting factors on each one of the listed criteria and come up with a numerical rating to compare to funding level. The problem is that different subfields stress different criteria.

8. **What factors either (a) facilitate or (b) inhibit international cooperation in high energy physics?**

(a) Facilitate

(1) Easy communication, computer networks, etc.
(2) Need for central, shared facilities
(3) Governmental pressure, i.e., budget constraints
(4) Shortage of talented scientists and engineers
(5) Tradition

(b) Inhibit

(1) Visa and customs complications
(2) Technology transfer restrictions
(3) University presence
(4) Nationalism
(5) Benefits to local industry in an increasingly competitive world economy

9. **Will spending of national funds on international facilities be to the detriment of national laboratories? What is the appropriate level of funding or national research efforts versus international efforts and how should these levels be determined?**

Not necessarily since one effect of increased international collaboration will be to convert one or more national laboratories to partially international laboratories. This would be true if we adopt Mode B (question 4). Ultimately, single purpose national laboratories or the HEP components of multipurpose labs will be reduced in scope anyway as the frontier new facilities appear. The appropriate funding levels for national vs. international labs must be based upon the science mission but also on the need to keep a base of operations in-nation. In Europe, each CERN member state has spent about as much in-country as their CERN dues. In the early years these in-country funds supported national accelerator laboratories. Later, many of these closed until only W. Germany maintains its own accelerator facility.

As we face a future of dwindling centers, a reasonable guess is that the U.S. would want to keep two strong facilities (or one very strong one and one less strong). In equilibrium, foreign contribtions to U.S. facilities would about equal U.S. contributions to foreign facilities, averaged over a sufficiently long period. Looking even further ahead, a world laboratory situated in SHANGRI-LA might require the contributions of about half the HEP budget of each country with the other half supporting the users groups and facilities in-country.

What is of great concern here is the balance of exploitation of foreign facilities vs. national facilities in the present mode. Here, scientific opportunities and minimization of duplicative research should be the main criteria.

10. **What does "world leadership" in high energy physics mean? What particular benefits accrue to the "world leader" versus "number two"?**

Why should national policy makers care whether or not the nation is first, second or third in high energy physics research?

The U.S. held world leadership in HEP from roughly 1950-1970. Some of the best and brightest of foreign scientists emigrated to U.S. universities and greatly enriched the scientific strength of the nation. Our exports balance was heavily "high-tech" and U.S. technology was overwhelming. The correlation was no accident. Great scientists attract students and recruit potential scientists.

Something happened about 1970 and by 1975, W. Europe was spending an increasing fraction of their GNP on basic research while the U.S. fraction was decreasing. Leadership passed to Europe clearly by 1980. Japanese investment in basic research also increased substantially in this period. Now, there is fierce technological competition and in many fields we have also lost our technological lead: machine tools, tires, computer chips, specialty steels, exotic alloys, etc. Again, the correlation could well be significant. World leadership does not mean dominance. Competition has always been an important ingredient in science because scientists do have human traits. Whereas it matters little if the UK is not a world leader in an important subfield of science, it means a lot if the U.S. is number two. High energy physics is the cutting edge. A direct line connects today's leaders in the field to their teachers who created quantum physics and the technological revolution. There is a lateral and symbolic link between leadership in this particular science and leadership in world affairs - it expresses confidence in the future and a recognition of the importance of culture in the affairs of great nations. Witness the U.S., a nation whose decline in science matches well against its decline in will and in influence. History is replete with similar examples.

11. **Are the experiences of international cooperation in high energy physics directly applicable to other fields of science? What lessons may be learned?**

That HEP is in the lead here is illustrated by the existence of CERN, a consortium of eleven European nations formed literally in the rubble of WWII. This is without doubt the most successful international laboratory, and has served as a model for other sciences. We should note that the U.S. was instrumental, even crucial, in the initiation of CERN. U.S. scientists and engineers contributed their greater experience in the years 1950-1960 to the research and to the design of the CERN machines. In particular, the invention of strong focussing at BNL in the late 50's was immediately communicated to the CERN designers and had a crucial effect upon the design of the CERN Proton Synchrotron.

Since HEP is the prototypical "Big Science" subject, the user mode and central shared facilities have been operative with increasing tempo since the early 50's. This has already had a big effect upon nuclear science, oceanography and other sciences where, increasingly, the facilities must be shared. Of course, astronomers lined up for telescope time much earlier.

The lessons have to do with management styles, with the sociology of large groups, with the problems of travel to the laboratory versus presence on campus. There is very little in the way of mechanisms for transmitting the experience of how to do and not to do these things.

Responses by Nicholas P. Samios, Brookhaven National Laboratory, to Questions for the Record of the Task Force on Science Policy: Review of International Cooperation in Big Science: High Energy Physics, April 25, 1985.

1. **What is the future prospect for the international cost-sharing of the next generation of high energy physics facilities, both in terms of construction and operation?**

   Answer to Question 1. I believe it makes sense and the time is appropriate that there be international cost-sharing for the next generation of high energy physics facilities. Whether it occurs depends on many factors, not the least of which is that all parties believe that it is of mutual benefit to do so. It is clear that these machines are becoming very large in scale and cost, that there will be, at most, one of each type and that they will be complementary in nature. What is needed is the conviction and the will to commit to the first such project and the cost-sharing feature of this on other endeavors will surely follow. At present, there is a consensus that a SSC type of machine is the logical next step in high energy facilities. The other major science centers have large construction projects under way (LEP at CERN, UNK at Soviet Union and TRISTAN in Japan), and these efforts preclude major roles in new starts until the early 1990's. As such, the U.S. is in the unique position of having the necessary expertise and personpower to aggressively pursue an R&D program for the next three years with a projected construction start in ~ FY 1989.

   For accelerator operations one probably should assume that actual accelerator operation costs should be borne by the host institution and its own funding entity: However, experimental equipment, etc., which involves continuing large financial outlays, can be expected to be shared internationally as is presently done at CERN by U.S. experimenters and by Japanese at U.S. laboratories.

2. **What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?**

   Answer to Question 2. Advantages obviously are that costs for U.S. would be reduced, thus possibly facilitating construction of a very large facility. Disadvantage is probably loss of control over facility by U.S. - funding becomes complicated in sense of requiring delicate international negotiations at highest levels - treaty negotiations, etc. Unless U.S. funding of such collaborations can be done on longer term basis than present "annual" budgets, there would probably be serious difficulties in treaty negotiations. Important issues on siting of the accelerator in U.S.A. are discussed in answers to other questions below.

3. **What would be the best worldwide configuration of high energy physics facilities from the point of view of science? How might this best be determined?**

4. **Should some or all future "big science" facilities be developed on the basis of international cooperation?**

Answer to Questions 3 and 4. It probably would not be in the best interest of science to have a monolithic planning body for world effort in HEP. Such bodies have often been less than clairvoyant on issues of best future facilities. The best worldwide configuration is one which contains significant complementarity in accelerator capabilities - and that seems to happen naturally as a result of the several distinct and separate planning bodies of the world. Communication is good between those bodies. Capabilities of studying physical phenomena at more than one institution is essential to the progress of science. Competition is essential and healthy.

5. **What is the trend of international collaboration in high energy physics? Is it increasing, decreasing or remaining relatively constant?**

Answer to Question 5. Collaboration on machine design is increasing. Collaboration in experimental programs across national boundaries is very common. Funding of experimental equipment to be used at accelerators in "foreign countries" is significant and growing vis-à-vis Japanese-American collaborative experimental programs at U.S. Accelerators, large experimental equipment being built in U.S. for use at HERA and CERN, etc.

6. **What attributes of high energy physics make international cooperation easy to achieve?**

Does the field have attributes that make international cooperation difficult?

Answer to Question 6. The diversity of facilities in different countries fosters international collaboration. Physicists are interested in solving physics problems and naturally collaborate across international boundaries in order to find experimental facilities appropriate to their particular experimental programs. Physics is foremost - so that although healthy national competition exists for new discoveries, the scale of experiments and their cost creates a climate very receptive to collaboration.

As a forefront field of science, of course, there is chauvinism. Credit to laboratories (which insures their long term viability) usually comes independent of national origin of the experimenter. Rubbia's discovery of the W & Z are accomplishments of a Harvard professor but that work is acknowledged to be a "CERN" - European coup. That is why on large facilities, i.e. construction of accelerators, it will be hard to foster true cooperation. However, this has not significantly hindered scientific collaboration because credit usually accrues to the scientist. In the above example both Rubbia the person and CERN the Laboratory get the credit.

7. **Has there been an overinvestment or underinvestment in high energy physics relative to other subfields of physics or other disciplines? How can the appropriate levels of investment in different subfields on disciplines best be determined?**

Answer to Question 7. Very difficult question. High Energy Physics addresses the most fundamental scientific issues. That it should receive very high levels of support is justified by its success and by the fact that the research requires large expenditures. It would be unreasonable to think that some other fundamental and very important scientific endeavors could automatically absorb funding going to HEP. They often have no need for such large resources to proceed at the forefront of their fields. There are, of course, financial - competitive issues.

Before answering the question of overinvestment or underinvestment in HEP specifically, one should answer the question regarding all of the U.S. science. The scientific endeavors of the country relative to their long term value to society are underfunded and over the last decades the support has not kept pace with either GNP or other measures of economic growth. This general issue is determined by governmental bodies - both executive and legislative. The general question of science funding cannot be otherwise.

The decision as to priorities for funding between different fields is best not done in a monolithic fashion. We have over the years been quite successful in science generally. The views of the scientific community as a whole has been influential in these global decisions which have basically been made by non-scientists - both in the executive and legislative branches of the government. Scientific successes in different fields have resulted in further support for that field. National needs in technology have also played a role in assigning priorities. It is probably best for science to have diffuse authority in these issues. Since science often involves very high risk and adventurism in attaining success, it is probably not good to put all the decision capability within one organization.

8. **What factors either (a) facilitate or (b) inhibit international cooperation in high energy physics?**

Answer to Question 8. Answered in 6 above.

9. **Will spending of national funds on international facilities be to the detriment of national laboratories? What is the appropriate level of funding or national research efforts versus international efforts and how should these levels be determined?**

Answer to Question 9. Spending of national funds on international facilities is to the detriment of national laboratories only if it stops being complementary. At present the balance is not unreasonable. If the U.S. should fall significantly behind in accelerator capabilities then obviously the need for us to spend in international endeavors will exceed the financial flow within the U.S. and that will be a serious detriment to the laboratories. The appropriate level will vary with time. Without a major new

start, our facilities over the next ten years will surely fall behind those available in Europe. In the next ten years, one might assume U.S. involvement abroad will be perhaps 10-20 percent of the U.S. effort in HEP.

10. **What does "world leadership" in high energy physics mean? What particular benefits accrue to the "world leader" versus "number two"?**

Why should national policy makers care whether or not the nation is first, second or third in high energy physics research?

Answer to Question 10. World leadership means that we are making important discoveries, recognized by the world community, winning prizes, etc., leading the way in accelerator development, producing new physicists of the highest quality, delivering significant spinoff useful to American industry, etc.

The image of the world leadership reflects on the respect we gain outside the U.S. for very significant intellectual accomplishments which bring confidence (in the whole world community) that the U.S. is in fact a world leader in technology and science. It brings a pride to our own populous, most important in inducing students to enter science and become not only researchers in pure science activities but in a very significant part of the whole technological (both civilian and military) establishment.

Intellectual challenge to the society is crucial to the maintenance of a high technology society. If the country engages in such an activity it must aspire to be first. Aspirations to be second or third in a field are sure to lead to general decline - you can't stay even in second place without the incentive to be best! A national decision in any field, that it is not important to be first, will surely lead to steady decline and we will find ourselves soon not second or third - but out. High energy physics is recognized by the best universities (in the U.S. and abroad) and by the majority of thoughtful and recognized scientists to be at the cutting edge of science. It is also so recognized by many young aspiring scientists. To relegate it to a position of removing the potential to be first, will have the effect of downgrading science in the U.S. - a sure way for us to obtain second-rate credentials.

11. **Are the experiences of international cooperation in high energy physics directly applicable to other fields of science? What lessons may be learned?**

Answer to Question 11. The healthy experiences in international cooperation in HEP are surely applicable to other fields of science. Successful activities in any scientific discipline have known no national boundaries and we should not erect them! The experiences in HEP are directly applicable to most big science endeavors: Astronomy, atmospheric science, space science, etc. International collaboration strengthens our own technological stance - by allowing time and vital exchange of information in all areas of technology.

One of the important lessons is mentioned above. Successful cooperative efforts cannot only be in the domain of people exchange, etc. The facility issue is important to maintain a superlative U.S. image. An Indian on a U.S. space shuttle may bring glory to himself but little to India. An American physicist at CERN brings glory to himself, not to the U.S. Important astronomical observations at the VLA bring glory to the U.S.A., not the country of origin of the astronomer.

November 1, 1985

Response to Supplementary Questions from the Science Policy Task Force Hearing of April 25, 1985 by Burton Richter

1. What is the future prospect for the international cost-sharing of the next generation of high energy physics facilities, both in terms of construction and operation?

The answer, I believe, depends on where the machine is constructed. For a machine to be built in the U.S. the possibilities are good for cost sharing with Pacific Basin countries. However, they are quite poor for the foreseeable future with Europe as a whole. A serious problem in discussing international collaboration with Europe is that there is no one to speak for "Europe" other than CERN, which quite properly has institutional interests as well as scientific ones. Further, Europe is in the midst of a massive accelerator construction effort which dwarfs what has gone on in the U.S. in the last five years. At CERN, LEP is under construction and an advanced antiproton source for the $p\bar{p}$ colliding beam facility is also under construction. In Germany the world's highest energy electron-proton colliding beam facility is under construction. Together, these projects cost on the order of 1 to 1.5 billion dollars, including staff costs. Thus I see no funds available from Europe for the foreseeable future. However, it is possible that certain individual countries in Europe would contribute to costs of a facility outside Europe.

The question of cost sharing for operation is more complicated. At present we have a rough "balance of trade" in high energy physics where U.S. physicists using foreign facilities are about balanced by foreign physicists using U.S. facilities. Where there is a balance of trade, outflow equals inflow, and there would be no cost saving through cost-sharing for operations, though there would be a considerable increase in administrative costs.

2. What are the advantages and the disadvantages of sharing the cost of big science facilities on an international basis?

There are two possible advantages to international cost-sharing. First, such cost-sharing may make possible the construction of a facility that is too expensive to be built in any other way. If this facility is affordable by the host country, international cost-sharing can reduce its financial impact.

The major disadvantage of the internationalization of the construction of big science facilities lies in the increased bureaucracy and in the increased costs incurred by what must be a more cumbersome design and construction procedure compared to what could be done were a single country to be the constructor.

3. What would be the best worldwide configuration of high energy physics facilities from the point of view of Science? How might this best be determined?

The best configuration of high energy physics facilities would, in the long run, include a very high energy proton–proton colliding beam storage ring and a very high energy electron–positron linear collider. Intermediate energy machines of both types would be very useful. The appropriate combination of machines and energies and locations is much more difficult to solve. This is clearly time dependent and science dependent. A proton machine covers all energies below its effective energy. Thus a very high energy proton collider might make an intermediate proton machine redundant.

Electron–positron colliders are quite different, and one machine does not efficiently span all of the energies below its maximum effective energy. Thus both intermediate energy and very high energy machines of this type might be appropriate.

There is already a consensus in the physics community on the appropriate energy for a very high energy proton–proton colliding beam machine. The question that is not settled is whether an intermediate machine is also desirable. There is also a developing consensus that in the electron–positron colliding beam field a machine of .5 to 1 TeV would be desirable to be eventually followed by a machine with an effective energy beyond that of the oft-discussed SSC.

4. Should some or all future "big science" facilities be developed on the basis of international cooperation?

I believe one should go international only when the advantages clearly outweigh the disadvantages. The difficulties and complexities of working in an international mode are usually underestimated.

5. What is the trend of international collaboration in high energy physics? Is it increasing, decreasing, or remaining relatively constant?

The trend is toward more international collaboration as the number of accelerator facilities decreases and as both the accelerators and experiments get larger and more costly. In experimental physics the fraction of U.S. work going on overseas as a fraction of the university support has remained roughly constant over time.

6. What attributes of high energy physics make international cooperation easy to achieve?

The time scale for applications coming from the basic research in high energy physics is extremely long, and so commercial and industrial advantage is not

important in making the siting decision. In addition, high energy physics has a long history of international cooperation on construction of facilities in Europe, and the use of facilities and the funding of experiments worldwide.

7. Has there been an overinvestment or an underinvestment on high energy physics relative to other subfields of physics or other disciplines? How can appropriate levels of investment in different subfields or disciplines best be determined?

The relative over- or underinvestment in a particular field of science is very difficult to determine. As a high energy physicist I of course do not believe that there has been any overinvestment in high energy physics. I would say that conditions for high level of investment in a particular field in basic research are the following:

A. The people should be excellent.

B. A rapid pace of discovery and advancement should be occurring.

C. The field should show some ability to set priorities on what has to be done.

If the three conditions are met, then I think the policymakers should set the level of support slightly below that which is claimed by the scientist to be required for the proper pursuit of their work. There is no way for the nonscientist to evaluate in detail the needs of a field of physics, and a mechanism has to be found to make the practitioners make responsible choices among alternatives. I think only budget pressure works.

It is also important when a field is supported and builds new facilities, to supply the necessary funds to operate those facilities and to support the university scientific community at a level such that those facilities can be properly used.

8. What factors either facilitate or inhibit international cooperation in high energy physics?

International collaboration is facilitated by having different types of facilities in different regions. Scientific interest will then lead some scientists to want to work at those machines in other regions, for some kinds of opportunities will only be available elsewhere. At the same time, we must have sufficient support to keep the home institutions healthy and those working outside the U.S. must be able to make significant contributions to the collaborations in which they are a part. Some balance must be struck between work outside and work inside our country.

International collaboration is inhibited by shortage of funds, for high-priority national efforts tend to have the first claim on available funds as well as by various bureaucratic barriers put up like many governments that discourage the easy international use of facilities. In our country visa problems, work permits for family members, customs barriers, etc. make life complicated for foreign scientists wanting to use our accelerators and contribute to our experiments. These matters are discussed in more detail in the Appendix of the "Annual Report to the Working Group on Technology, Growth, and Employment" by the Summit Working Group on High Energy Physics; April 1985; DOE/ER-0223.

Responses to Questions for the Record
Professor Jack Sandweiss
Yale University

1. **What is the future prospect for the international cost-sharing of the next generation of high energy physics facilities, both in terms of construction and operation?**

Answer to Question 1. The prospect is good for a limited cost sharing of construction costs for the next generation of high energy physics facilities. It is not unreasonable to imagine that Japan and Canada, for example, might participate in the construction of the proposed Superconducting Super Collider (SSC) in the United States. Although such participation could be substantial, it is very likely to constitute a fraction of the total construction cost. An example of such a construction collaboration is afforded by the Hadron-Electron-Ring Accelerator (HERA) project in the Federal Republic of Germany. The German government bears abnut 70 percent of the construction cost and the foreign collaborators bear the remaining 30 percent. Overall responsibility for the project is centralized in the Deutsches Elektronen-Synchrotron (DESY) laboratory in Germany.

Because Europe, as a region, is very interested in maintaining a forefront capability in high energy physics, it is unlikely that there would be European collaboration in the construction of a new United States accelerator, such as the SSC.

Sharing of operating costs is conceivable but cumbersome. A way of effectively sharing such costs is for foreign collaborators to contribute to the (expensive) instrumentation required to use the accelerator. Such instrumentation cost sharing is now a widespread practice in high energy physics.

2. **What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?**

Answer to Question 2. The major benefit of cost sharing of big science facilities on an international basis is the possibility of providing science, worldwide, with facilities which would not otherwise be available or which would be available only after considerable additional delay. Such cost sharing would also enhance the exchange of scientific information and the general quality of international collaboration.

The disadvantages arise from the additional complexity inherent in a multi-nation cost sharing arrangement. These might involve project delays while the details of the cost sharing are negotiated and/or a loss of management flexibility during the course of the project because of constraints arising from the cost sharing agreements.

On balance, if significant cost sharing can be achieved, it would appear that the benefits outweigh the disadvantages.

3. **What would be the best worldwide configuration of high energy physics facilities from the point of view of science? How might this best be determined?**

Answer to Question 3. In my opinion, an essential ingredient of the optimium world configuration of high energy facilities includes an SSC, in the United States, coming on-line for physics research by the mid-1990's. A high luminosity hadron collider is universally recognized as the clear priority, worldwide, for high energy physics. In no other way can some of the central issues of the science be addressed.

The European efforts in high energy physics will be concentrated on LEP until the early 1990's. The hadron collider project is too large for Japan. However, such a project fits well--at least scientifically--in the United States program. The United States will complete its current projects, the TEVATRON at Fermilab and the Stanford Linear Collider at Stanford Linear Accelerator Center (SLAC), by 1987. Some of the other older facilities, the PEP storage ring at SLAC and the Alternating Gradiant Synchrotron (AGS) at Brookhaven, are likely to be obsolete by the mid-1990's. Thus, the SSC is appropriately timed for the United States program.

The European high energy community is, of course, concerned about the long range future of CERN and DESY. There is a clear intent to maintain a forefront position for Europe in the field of high energy physics. It is too early now to say what the correct choice for Europe and CERN will be. There are several possibilities which are, and will continue to be, under intensive study. These include a hadron collider in the LEP tunnel, an e-p machine using LEP as the electron accelerator, and more exotic schemes involving accelerator techniques which are still in the research and development phase. It is also clear that the European plans will be affected in a major way by the United States action with respect to the SSC.

In my opinion, the best way to "reach the optimum" is to maintain and increase the exchange of information on the planning and the planning process in each region. There is, I believe, general international agreement that major duplication of facilities can no longer be afforded. Given this view and full information exchange, I believe no other formal mechanism is required or desirable.

4. **Should some or all future "big science" facilities be developed on the basis of international cooperation?**

Answer to Questions 4. The cost sharing of new facilities on an international basis would be a "positive good" as discussed in the answer to question one. However, it would not be desirable to establish a "world laboratory" supported internationally to become the world center for high energy physics.

Answer to Question 4 - Continued. There are several reasons for this opinion. The first and perhaps the most important is that the science requires several different types of facilities. There are good fundamental reasons for believing that this characteristic will continue. Thus, there is no reason not to maintain regional high energy physics centers whose programs complement one another. Indeed, there are considerable efficiencies of management, operation and utilization of regional (as contrasted with world) facilities. Finally, many of the benefits to related sciences and to society are enhanced if the major high energy facilities are "closer to home".

5. **What is the trend of international collaboration in high energy physics? Is it increasing, decreasing or remaining relatively constant?**

Answer to Question 5. International collaboration has traditionally been a strong feature of high energy physics research and the trend has been to ever increasing levels of such collaboration. At first, there was excellent exchange of information and techniques, often supported by frequent visitor exchanges. Later, joint design and construction of major experimental apparatus developed. Most recently, the collaboration in construction of major accelerator facilities has begun. As noted in the answer to question number one, the HERA project in the Federal Republic of Germany is the first such facility to be constructed by an international collaboration (under the overall leadership of the West German DESY Laboratory).

6. **What attributes of high energy physics make international cooperation easy to achieve?**

Does the field have attributes that make international cooperation difficult?

Answer to Question 6. High energy physics is a fundamental science which seeks to learn about the basic structure of matter and energy. As such, it has a broad interest and appeal to scientists worldwide. There is a true international community in the field and there is general agreement as to what constitutes good research and as to the promising directions for future work. These features are the basic reasons for the growth and success of international collaboration in high energy physics.

A secondary feature of importance in this regard is the large scale of the facilities and experiments. This feature makes collaboration, in general, a favored strategy in the field. Thus, European high energy physicists have achieved much greater results by collaborating via CERN than they would have in a pattern of smaller national efforts.

One factor that must be kept in mind, however, is the desire of the major regions of the world to maintain a strong and healthy high energy physics research program in their own region. Such desires do not prevent international collaboration, but they do affect the form which it can take. See, for example, the discussion of the next generation plans of the United States and Europe given in the answer to question three.

7. **Has there been an overinvestment or underinvestment in high energy physics relative to other subfields of physics or other disciplines? How can the appropriate levels of investment in different subfields on disciplines best be determined?**

Answer to Question 7. The question of the proper balance of investment in the different scientific fields and in science in general is a most difficult one. In my opinion, the United States program, involving the interplay between scientists, government agencies and Congress is a good one. The role of Congress in making the final decisions amongst the various societal goals seems to me to be an appropriate one.

In my view, there has not been an overinvestment in high energy physics. The guiding principle should be that the investment be sufficient, with prudent and economical management, to ensure that the field is healthy and viable in the United States. High energy physicists have been responsible in turning off facilities which do not meet the above criterion and the real costs of the field have not changed very much in the last decade. High energy physics in the United States does now require an incremental increase for a limited, but substantial time, in order to provide a facility which is crucial to the progress of the subject and the viability of the program.

8. **What factors either (a) facilitate or (b) inhibit international cooperation in high energy physics?**

Answer to Question 8. This question is addressed in the answer to question number six.

9. **Will spending of national funds on international facilities be to the detriment of national laboratories? What is the appropriate level of funding or national research efforts versus international efforts and how should these levels be determined?**

Answer to Question 9. The basic principles in balancing efforts at national versus international facilities should, in my view, be to maximize both the scientific results and the health of the United States program. In detail, the issues are complex. Facilities abroad often provide opportunities for United States scientists which are not available at home. Indeed, the growing complementarity of high energy facilities on a worldwide basis means that this situation will continue and will become more prevalent. At the same time, sufficient resources must be devoted to United States facilities so that they continue to be forefront efforts.

In practice, if the United States facility posture is one which has unique, forefront facilities, the "balance of trade" between the outflow of United States physicists and money will be compensated by an inflow of foreign physicists and money using our facilities. It should be noted again that both of these activities are usually carried out via international teams of collaborators. It is interesting to note that, at present, the net "balance of trade" in high energy physics is favorable to the United States both in a manpower and a financial sense.

10. **What does "world leadership" in high energy physics mean? What particular benefits accrue to the "world leader" versus "number two"?**

Why should national policy makers care whether or not the nation is first, second or third in high energy physics research?

Answer to Question 10. "World leadership" in high energy physics would mean that the leading country had both the most advanced facilities and the research workers who were leaders in the discoveries made with those facilties. It is possible to distinguish classes of world leadership. On one hand, the leading country might have a complete dominance in the field or on the other hand, a country might be in a position of world leadership which, in a broad sense, is shared with other countries or regions.

Given the costs of high energy facilities and the general trend to international complementarity, it is unrealistic to aim at a position of dominance for the United States. So, we should consider the benefits which accrue to being among the class of world leaders in the field as compared to being a clear second class country.

An incomplete list of these benefits would include the following:

1. High energy physics is a fundamental science. It probes the basic structure of matter and energy and is a clear frontier field in science. It is difficult to imagine a strong United States scientific culture which did not include that large region of the frontier of scientific research which is represented by high energy physics. A second-rate United States stance in high energy physics would be a clear signal of the willingness of the U. S. to accept second-rate status in science and technology in general.

2. The techniques developed for high energy physics have been very useful for other sciences and for industry. The development of accelerators has made synchrotron light sources available for condensed matter physics and for biology, for example. The methods of particle detection have had important application in nuclear medicine. The development of large superconducting magnet systems promises new applications in NMR imaging, electric power transmission and in other areas. Many other examples could be given of the applicability of the basic techniques of high energy physics—the production and manipulation of high energy beams and the detection of subatomic particles.

3. High energy physics traditionally has pushed at the limits of the state of the art across a wide range of technologies—electronics, computers, optics, systems, cryogenics, etc. It has stimulated developments in these technologies in an open fashion, which maximizes the availability and usefulness of the developments across the breadth of United States science and industry.

Answer to Question 10 - Continued.

4. While application of new discoveries in fundamental science are notoriously hard to predict, history has been consistent in showing that every fundamental advance in our basic understanding of nature has led to applications with significant impact on human life. It is not unreasonable to believe that in some fashion, as yet unknown to us, this history will repeat itself. History also indicates that to be able to respond to the new potential for application, the infrastructure of science and technology, which is represented by a healthy research field, is essential. For example, the United States would not have been able to respond to the discovery of nuclear fission (made in Germany) if it had not been for the cadre of nuclear physicists, many of them recent immigrants, working in United States universities.

11. **Are the experiences of international cooperation in high energy physics directly applicable to other fields of science? What lessons may be learned?**

Answer to Question 11. Some of the experience gained in international cooperation in high energy physics may be applicable to other fields. As noted in the answer to question six, the two attributes of high energy physics which encourage international cooperation are its fundamental character and the need for large scale operations. Many fields share the aspect of being fundamental scientific disciplines, but fewer require the scale of operation characteristics of high energy physics.

Among the practices in high energy physics which have encouraged international cooperation, perhaps the most important has been the policy at each major facility to accept and consider experimental proposals on an equal footing, whatever the country of origin of the proposing scientists. This policy has led to the growth of international teams in experiments which, in turn, has paved the way for possible international collaboration in facility construction.

Professor Maury Tigner

Questions of the U.S. House of Representatives
Science Policy Task Force

1. What is the future prospect for the international cost-sharing of the next generation of high energy physics facilities, both in terms of construction and operation?

While international collaboration in the planning for new experimental facilities in high energy physics and in their utilization has been excellent, the prospect for international cost-sharing for future facilities is not good in the near future. Potential partners with the United States for cost sharing in the next generation of U.S. facilities would be Western Europe, Japan, or Canada. Sharing on a worldwide basis involving Socialist or Third World countries is much more remote.

Western Europe has embarked on the construction of a new generation of frontier facilities including the LEP 27-kilometer circumference electron-positron ring and the HERA electron-proton collider. These facilities require not only funds for construction but also substantial sums for the major particle detectors needed to exploit these machines. As a result of these requirements and the expected funding profiles for European high energy physics, no flexibility within European high energy physics is apparent until 1991 or 1992. Understandably, Europeans appear unwilling at this time to commit that flexibility for contributions to U.S. facilities. Additional European plans, in particular the large hadron collider (LHC) in the LEP tunnel are under discussion. This does not mean that European international participation in the SSC program is excluded; on the contrary, some such participation is now in effect in respect to design of that machine, and we anticipate considerable international participation in terms of providing equipment for utilization of the SSC during its operating phase. Although some contributions during the construction phase are not excluded, those will not be sufficiently substantial to have a significant effect on the total SSC construction cost.

The situation in respect to Japan is somewhat different. The Japanese are initiating studies to plan their construction program in high energy physics following completion, expected in 1986, of the electron-positron collider (TRISTAN). Participation in the SSC is one of the options under consideration. These studies are expected to be completed in one to two years. Whatever the outcome, considering the size of the Japanese high energy physics program, it is

unlikely that potential contributions by Japan to the SSC would be a substantial fraction of total construction cost; moreover, contributions, if any, would be in the form of high technology hardware, rather than financial.

Because of geographic proximity, Canada would be a natural partner to participate in the SSC. However, the Canadian high energy program (and GNP) is significantly smaller than the one in the U.S. and thus any potential contributions would be quite small. In addition, the Canadians are interested in pursuing construction of a large medium energy facility, TRIUMF, which would absorb most of their available funds.

For the above reasons I recommend that planning, design and authorization for the SSC proceed on a national basis. At the same time, international participation, financial and otherwise, should be sought with high priority from other countries, in particular Japan.

2. What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?

The main advantage lies in the possibility of being able to build a facility that could not be built in any one single country. In addition cost savings would result but those probably would not be as substantial as one might normally envisage since the facility would very likely be more complex than if built by a single country. Finally, such international cooperation might bring additional intangible benefits, like better exchange of scientific and technological know-how, furthering of international understanding, broader education for graduate students, etc. These benefits, however, accrue mainly through international cooperation in the use of the machine and it is not clear how much cost sharing in construction would contribute here.

The main disadvantage would be that the site of the facility might be outside of the U.S. There is also a risk of a long delay in establishing the laboratory. A long time will be required to establish the appropriate agreements and to choose a site.

Whether there is actual international cost sharing for a given facility or not, there are various mechanisms for international coordination in place which will avoid duplication of expensive facilities in the future. If international cost sharing of most, if not all, future machines becomes established, the net saving to the U.S. could become small or non-existent.

3. <u>What would be the best worldwide configuration of high energy physics facilities from the point of view of science? How might this best be determined?</u>

A map is attached which shows the worldwide configuration of high energy physics facilities now existing or planned. The existing and committed facilities in the United States will provide decreasing opportunities for high energy physics by the first half of the next decade. The next logical step, both from the point of view of optimizing the worldwide configuration and filling this opportunity gap is the construction in the United States of the SSC. This move has been widely discussed in international conferences and by the International Committee of Future Accelerators (ICFA), a committee established by the International Union of Pure and Applied Physics. Construction of the SSC is supported by the majority of the international community. There is an emerging international consensus that, subsequent to the SSC, an accelerator to advance the electron-positron collider frontier should be established, but that such a machine will require the evolution of new technology. Thus the timing of such a further step is not now predictable. Depending on the richness of the physics uncovered by facilities now under construction or committed, in particular the Tevatron I at Fermilab, the CERN Proton-Antiproton Collider, the SLC collider at SLAC, LEP and HERA in Western Europe and TRISTAN in Japan, the establishment of additional subfrontier facilities may become advisable and justifiable, but it is too early to seek agreement on such moves.

4. <u>Should some or all future "big science" facilities be developed on the basis of international cooperation?</u>

As discussed in the answers to other questions there are some advantages to developing "big science" facilities on the basis of international cooperation. However there are three reasons why some "big science" facilities should be developed on a national or regional basis rather than an international basis. (CERN is an example of a regional facility.) First, some scientific areas, because of their technological significance, may be of major interest only to a particular nation or region. The science and technology of desalinization is an example. Second, "big science" facilities interact actively with industry, supporting and stimulating new technology. This effect is strongest when the facility is national or regional. Third, when "big science" facilities are national or regional, they best support the education of scientists and engineers. Hence a major industrial nation such as the United States should maintain a balance between international "big science" facilities and national or regional facilities.

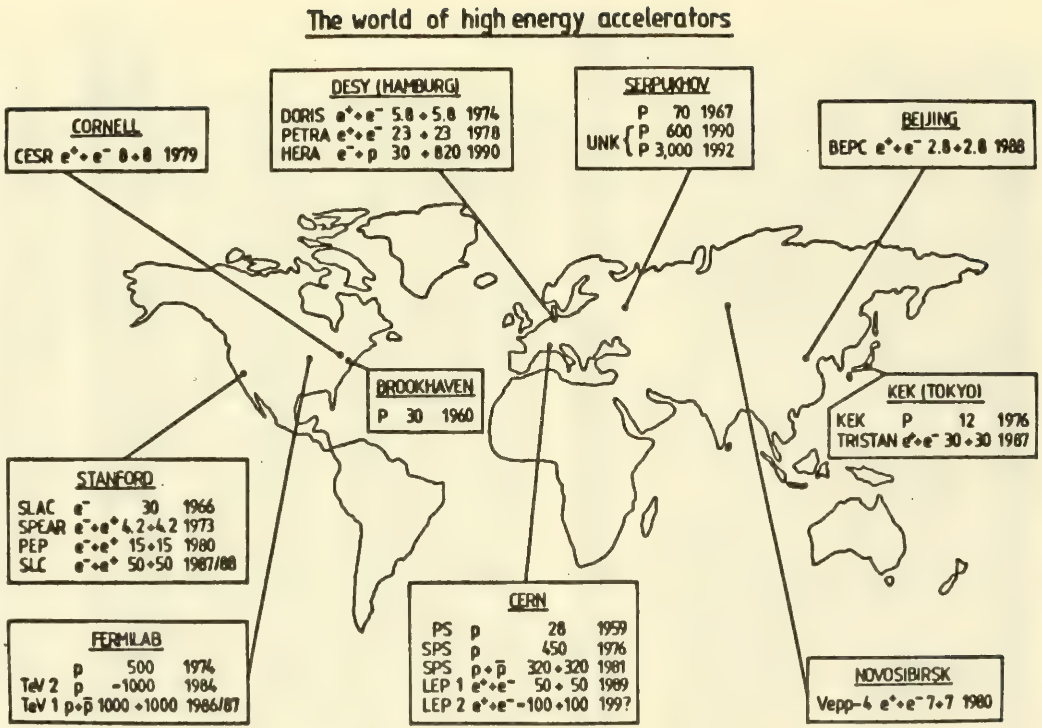


Figure 1

Each accelerator is defined by the particles accelerated, the energy in GeV, and the date of completion

5. What is the trend of international collaboration in high energy physics? Is it increasing, decreasing or remaining relatively constant?

The trend of international collaboration is increasing because of a growing diversity of facilities. Collaboration began to increase with the advent of the ISR at CERN and FNAL in the U.S. It continues with the $Sp\bar{p}S$, Tevatron I (2 TeV $p\bar{p}$ collisions) and Tevatron II (800-1000 GeV fixed target), LEP, SLC, TRISTAN and HERA, a set of facilities with unique or nearly unique colliding beam capabilities. The spectrum of these capabilities covers high energy $\bar{p}p$, e+e-, and e-p collisions and high energy fixed target program. Even SLC and LEP, superficially quite similar, have important differences. Thus SLC has a very small beam size and polarization capability. LEP will have a high luminosity and ultimately the capability of reaching above 170 GeV (threshold for W boson pairs). Thus one can expect even a further growth of large international collaborative efforts, driven by common interests of European, Japanese and American physicists.

6. What attributes of high energy physics make international cooperation easy to achieve? Does the field have attributes that make international cooperation difficult?

The intellectual tradition of the West with its keen interest in understanding nature in scientific terms, independent of other sectarian or national values, make basic science in general, and high energy physics in particular, relatively easy areas for international collaboration and cooperation as is borne out by history. Almost since its inception, the pursuit of high energy physics has required sharing of large, expensive facilities. Thus, modes of collaboration and cooperation across various kinds of political and geographical boundaries have been developing for many years.

There are economic, educational, cultural and national pride aspects to basic science and high energy physics is no exception. In a resource-limited world, the desire to be the first to know and to benefit from that knowledge, and the technological spin-off from the knowledge itself and from the process of its acquisition, does erect some barriers to collaboration and cooperation.

7. Has there been an overinvestment or underinvestment in high energy physics relative to other subfields of physics or other disciplines? How can the appropriate levels of investment in different subfields or disciplines best be determined?

The amount of investment in high energy physics or any other scientific area should be measured by the degree to which the Nation wishes to maintain cutting-edge research in the area. This is the

research which has the best possibilities of answering the major unsolved questions, of breaking into new areas in the study of nature, and of introducing new technology. In some areas such as astronomy, space science, or high energy physics, cutting-edge research requires large facilities with commensurate construction and operating costs. In other areas such as chemistry and solid state physics less investment is required to do some types of cutting-edge research. But even such areas have begun to need large facilities such as synchrotron light sources and pulsed neutron sources to do forefront research.

Considering high energy physics, the nation's investment has led in the past to our leadership in this field. A markedly smaller investment would not have enabled us to achieve this. This is demonstrated by the fact that Western Europe was able to equal this nation's achievements in high energy physics only when the European investment had become substantially larger than our investment. If this nation's investment is not maintained, we shall not be able to maintain a forefront position in high energy physics research.

8. What factors either (a) facilitate or (b) inhibit international cooperation in high energy physics?

International cooperation in high energy physics is facilitated by a number of factors as follows:

(a) The field operates without communication restrictions in all nations and as a result the practitioners of the field are well acquainted and new data are available worldwide.

(b) There exist a substantial number of international conferences at which there is full information exchange of recent experimental results, theoretical work, and technological opportunities and achievements.

(c) The interest in high energy physics is shared worldwide among physicists of all nations.

(d) The cost of construction of new facilities, as well as the cost of exploitation of existing ones, is sufficiently high that all nations recognize that international communication and coordination are essential to optimize national programs.

International cooperation in high energy physics is inhibited by a number of factors:

(a) Governmental formalities, in particular those of the Soviet Union, are time-consuming and to some extent unpredictable in

results. Therefore, participation of physicists in cooperative experimental work is frequently difficult to schedule.

(b) Travel cost is a significant cost item in times of tight budgets.

(c) Export restrictions cause delays in transfer of apparatus to agreed international joint ventures.

(d) There continue to be problems in the visa regulations and other restraints of various governments which impede the optimum composition of international teams.

(e) Cooperative international ventures, in particular those involving substantial joint funding of multi-year undertakings, require a long planning lead time and long-range commitments. This is difficult to achieve under an annual funding cycle.

9. Will spending of national funds on international facilities be to the detriment of national laboratories? What is the appropriate level of funding or national research efforts versus international efforts and how should these levels be determined?

Naturally there is competition between funds spent on international facilities in high energy physics and the commitment of such funds to national activities, both at the national laboratories and U.S. universities. However, such competition is of a similar nature as that among purely national activities. Funds for international facilities are justified in terms of the benefits to the work of U.S. high energy physicists utilizing such facilities. I do not believe that one can, or should, make a decision as to what is an appropriate level of funding for international efforts. Rather, the use of national funds on international facilities should be judged in competition with purely national needs using criteria that take into account benefits to U.S. physicists and to the progress of knowledge worldwide. Such judgments are best made by peer groups such as the Department of Energy's High Energy Physics Advisory Panel (HEPAP) reporting to governmental authorities having line responsibility for the program. Unless U.S. national construction efforts and funding for equipment projects (such as large detectors) remain competitive, it is unavoidable that an increasing function of the U.S. effort will continue to migrate abroad.

10. What does "world leadership" in high energy physics mean? What particular benefits accrue to the "world leader" versus "number two"?

Why should national policy makers care whether or not the nation is first, second or third in high energy physics research?

In the future one can conceive of only one or two forefront machines, so the idea of world leadership requires the location of at least one such facility in the United States.

History has always taught us that the knowledge acquired through basic research is ultimately of benefit to mankind. One hears arguments that high energy physics is of no practical use, but we have heard that before about nuclear physics and even about electricity in Faraday's time.

The spirt of a nation is certainly related to the extent to which its resources are extended to activities which transcend the prime goals of maintaining the well being of the population. An example of such a loss of spirit can be seen in the United Kingdom, where the move to reduce funding for basic research is further evidence of the decline of a great nation as viewed from the outside. High energy physics is one of many such activities for which the United States has the resources to participate. Our tradition as the originators of the particle accelerators, and our consequent achievements in the understanding of the fundamental properties of matter make high energy physics a most natural field to continue vigorously.

There is a certain amount of prestige that accrues to a nation that is a leader in any scientific field. The discoveries of new phenomena frequently receive prominent mention in the press and their discoverers are awarded numerous scientific prizes. On the other hand, confirmations of these discoveries, at some time later on, have clearly a lot less impact and receive less publicity. High school and college students are much more likely to go into scientific and engineering fields if they perceive that there are good opportunities in science for them in their own country. If a country is clearly "number two" or "number three" in a certain field, it is less likely that the field will attract new young practitioners.

11. Are the experiences of international cooperation in high energy physics directly applicable to other fields of science? What lessons may be learned?

The CERN laboratory offers the most experience in international cooperation in high energy physics, although CERN is a regional rather than a truly international facility. The positive experiences are: combined use can be made of the scientific and technical talents of the participating nations; combined use can be made of the industrial resources of the participating nations; costs are shared; larger facilities can be built than would be possible without international collaboration; the need for long-range agreements between the participating nations leads to financial and organizational stability for the shared facility; and international cooperation in

construction projects and research helps to further international goodwill and understanding.

The negative experiences are: scientific and technical inefficiences arise because there is a need to allow each nation to participate in most activities of the facility; total construction and operating costs tend to be high because of the aforementioned inefficiencies; the need for long-range agreements between nations can make it difficult to start new research programs or change old programs. In a truly international facility these negative experiences might be accentuated.

Another form of international cooperation involves one nation or region taking primary responsibility for constructing and operating a large science facility, with other nations contributing in important ways. Examples are the use of Fermilab and SLAC by Japanese physicists, and the use of DESY by non-German physicists. In these cases the "outside" physics groups contribute from their nations' science budgets: equipment, accelerator operating funds, or R&D funds. The physics groups themselves contribute scientific and technical personnel. This tends to be the most efficient form of international cooperation because a single nation has the primary design, construction, and operation responsibility for the facility.

All of these positive and negative experiences can be used by other fields of science to study how various forms of international cooperation could enhance the research activities in their fields.

6/20/85

APPENDIX 3

Additional Statements for the Record

DR. NICHOLAS P. SAMIOS, DIRECTOR
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK

DISCUSSANT BEFORE THE
TASK FORCE ON SCIENCE POLICY
COMMITTEE ON SCIENCE AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES

THURSDAY, APRIL 25, 1985

NICHOLAS P. SAMIOS

BROOKHAVEN NATIONAL LABORATORY

I thank the Committee for the opportunity to testify on the question of "International Cooperation in Big Science: High Energy Physics."

My first comments have to do with the fact that there has been a history of international cooperation in high energy physics since the beginning of the 1950's. Close collaboration was established between the accelerator builders at Brookhaven National Laboratory and CERN in the construction of the Alternating Gradient Synchrotron and the Proton Synchrotron. This involved exchange of information and joint meetings--resulting in the successful completion and operation of two excellent and scientifically productive accelerators. Since that time activities have expanded so that not only do we interact with machine builders all over the world, but in addition American scientists have been and are involved in large scale experiments at foreign establishments and vice versa. This interchange has even been formalized via bilateral agreements between the United States and Japan, USSR and the People's Republic of China. A further step was taken with the creation of the International Committee for Future Accelerators (ICFA) in the late 1970's, in anticipation of the construction of a multi-national Very Large Accelerator (VLA). The present composition of the Committee consists of representation from the United States, Western Europe, USSR, Japan and India. The latest meeting took place three weeks ago in Bombay, India, which I attended as a delegate. For your information I attach the latest Guidelines and the Membership List of ICFA Panels.

At the present time, we at BNL are in the process of negotiating an agreement with the Deutsches Elektronen-Synchrotron (DESY) at Hamburg, collaborating in various technical areas in accelerator R&D which we believe will be of great mutual benefit.

The pertinent question is the funding of the construction of new and costly accelerators. As noted above, the communication in high energy physics is excellent and there is an attempt to avoid duplication of facilities. However, this objective is not always successful, witness the existence of both PETRA and PEP. The construction of these facilities can be viewed in prospective if one understands that, when at a given time the next step in science is rather obvious and promises exciting results, competition is inevitable. As long as the expense was not excessive, having similar machines in different parts of the world was a positive force--in terms of competition, accuracy and verification and exploitation of new and exciting results. This era is certainly coming to an end. The question now is how to foster and achieve the orderly construction of the next generation of accelerators. To first order, experimentalists would prefer to have the facility in their back yard. Since that is not possible, I believe the high energy community puts a higher priority on accelerator construction than on its location and as such would accept any reasonable site. The important point is to set up and implement procedures that will lead to the successful construction of the accelerator, on an international basis, without unnecessary preconditions. One should not require, for instance, a signed international agreement before entering into substantive discussions. One hopes that ultimately logic will prevail, that when one considers ongoing activities, resources and time scales, a plan will emerge that makes sense and satisfies reasonable people. The name of the game is to set up procedures to achieve goals so that our activities in high energy physics will be complementary on an international as well as a national scale and thus will provide a cost effective frame for unraveling nature's secrets.

INTERNATIONAL COMMITTEE FOR FUTURE ACCELERATORS

GUIDELINES

To promote international collaboration in all phases of the construction and exploitation of very high energy accelerators.

To organize regularly world-inclusive meetings for the exchange of information on future plans for regional facilities and for the formulation of advice on joint studies and uses.

To organize workshops for the study of problems related to super high energy accelerator complexes and their international exploitation, and to foster Research and Development of necessary technology.

International Committee for Future Accelerators
Sponsored by the Particles and Fields Commission of IUPAP

February 1985

MEMBERSHIP LIST OF ICFA PANELS

1. SC MAGNETS AND CRYOGENICS	Chairman : G. Brianti
Europe (3)	G. Brianti (CERN) C. Daum (NIKHEF) H. Desportes (CEN Saclay)
USA (3)	P. Reardon (BNL) C. Taylor (LBL) A. Tollestrup (FNAL)
Japan (2)	M. Hirabayashi (KEK) S. Mitsunobu (KEK)
USSR (3)	K.P. Myznikov (Serpukhov) A.I. Ageev (Serpukhov) V.A. Titov (Efremov Inst.,Leningrad)
(+ 1)	I. Shelaev (Dubna)
Fourth Region (3)	Yan Lu-guang (Inst. Elec. Engineering, Beijing) Poh-Kun Tseng (Nat. Taiwan Univ. Taipei) P. Chadha (BARC, Trombay)
2. BEAM DYNAMICS	Chairman : N. Dikansky
Europe (3)	E. Keil (CERN) A. Piwinski (DESY) S. Tazzari (Frascati)
USA (4)	A. Chao (SLAC) R. Talman (Cornell) C. Pellegrini (BNL) C. Leemann (LBL)
Japan (2)	T. Suzuki (KEK) T. Katayama (INS, Tokyo)
USSR (3)	V.I. Balbekov (Serpukhov) A.A. Kolomensky (Lebedev) N. Dikansky (Novosibirsk)
(+ 1)	B.P. Dmitrievsky (Dubna)
Fourth Region (2)	Fang Shou-Xian (IHEP, Beijing) Chiu-Nan Chang (Nat. Normal Univ. Taipei)

3. <u>NEW ACCELERATOR SCHEMES</u>		Chairman : A. Sessler
	Europe (3)	M. Eriksson (Maxlab, Lund) J. Lawson (RAL) J. Le Duff (Orsay)
	USA (4)	R. Palmer (BNL) A. Sessler (LBL) R. Jameson (Los Alamos) P. Morton (SLAC)
	Japan (2)	T. Kamei (KEK) H. Yoshioka (INS, Tokyo)
	USSR (4)	A.C. Amatuni (Yerevan) Yu.P. Vahrushin (Efremov Inst.,Leningrad) A.N. Lebedev (Lebedev) V. Balakin (Novosibirsk)
	(+1)	B. Sarantsev (Dubna)
	Fourth Region (2)	K.C. Cheng (Syn. Rad. Res. Centre, Taipei) S.S. Ramamurthy (BARC, Trombay)
4. <u>INSTRUMENTATION</u>		Chairman : T. Ekelof
	Europe (4)	C. Fabjan (CERN) T. Ekelof (Uppsala) A.H. Valenta (Siegen) D.M. Binnie (IC, London)
	USA (4)	J. Pilcher (Chicago) M. Breidenbach (SLAC) D. Nygren (LBL) D. Hartill (Cornell)
	Japan (2)	S. Iwata (KEK) H. Okuno (INS, Tokyo)
	USSR (3)	Yu. M. Antipov (Serpukhov) V.A. Liubimov (ITEP) V. Sidorov (Novosibirsk)
	(+1)	Yu. K. Akimov (Dubna)
	Fourth Region (2)	C. Chang (Syn. Rad. Res. Centre,Taipei) ....

CURRICULUM VITAE

Nicholas P. Samios

Born March 15, 1932, New York, New York

1949		Stuyvesant High School	
1953	A.B.	Columbia College	Physics
1957	Ph.D.	Columbia University	Physics
1956 - 1959		Department of Physics Columbia University	Instructor
1970 - Present		" "	Adjunct Professor
1969 - 1975		Department of Physics Stevens Institute of Technology	Adjunct Professor
1959 - 1962		Brookhaven National Laboratory Department of Physics	Assistant Physicist
1962 - 1964		" " "	Associate Physicist
1964 - 1968		" " "	Physicist
1965 - 1975		" " "	Group Leader, Nuclear Interactions Group (Changed to "New Group"
1968 - Present		" " "	Senior Physicist
1975 - 1981		" " "	Chairman Department of Physics
1981		Brookhaven National Laboratory High Energy and Nuclear Physics	Deputy Director
Jan. 1982		Brookhaven National Laboratory	Acting Director
May 1982-Present		" " "	Director

AWARDS

1980 E. O. Lawrence Memorial Award for leadership in the study of elementary particles, in particular for the discovery of the Omega minus particle and the first charmed baryon.

1980 New York Academy of Sciences Award in Physical and Mathematical Sciences.

List of Memberships Attached

MEMBERSHIPS

Nicholas P. Samios

1953	Member, Phi Beta Kappa
Jan. 1964	Fellow, American Physical Society
Mar. 1966 - Feb. 1969 Mar. 1968 - Feb. 1969	Member, BNL Council Chairman, BNL Council
Jan. 1967 - Dec. 1968	Member, Program Advisory Committee Stanford Linear Accelerator Center (SLAC)
Feb. 1968 - Dec. 1968	Secretary, Subpanel D ERDA High Energy Physics Advisory Panel (HEPAP)
July 1968 - Jan. 1972	Member, AUI High Energy Study Committee
April 1969- 1972	Member, Princeton-Pennsylvania Accelerator Visiting Committee
Dec. 1969 - Spring 1974	Member, National Accelerator Laboratory Program Advisory Committee
Sept. 1973- 1975 Sept. 1975- Present	Member, BNL High Energy Advisory Committee Ex Officio
Oct. 1974 - Jan. 1975	Member, Evaluation Team N.Y. State Education Dept. Doctoral Education Project
	Div. of Particles & Fields, American Physical Society
Jan. 1974 - Jan. 1975	Vice Chairman, Chairman: Program Committee
Jan. 1975 - Jan. 1976	Chairman of Division
Jan. 1976 - Jan. 1977	Member, Executive Committee
July 1972 - June 1976	Member, SLAC Scientific Policy Committee
July 1976 - June 1978	Chairman, PEP Experimental Program Committee (of SLAC and Lawrence Berkeley Laboratory)
Oct. 1976 - 1980	Member, High Energy Physics Advisory Board (HEPAP) of DOE.
1980	Member, New York Academy of Sciences
May 1981	Fellow, American Academy of Arts & Sciences
April 1982	Member, National Academy of Sciences
January 1983	Member, Yale University Committee for the Physical Sciences and Engineering
January 1984	Member, International Committee for Future Accelerators (ICFA)
February 1984	Member, Evaluation Team* for Middle States Association of Colleges and Schools, Commission on Higher Education (*University of Pennsylvania)

STATEMENT OF

PETER M. McINTYRE

TEXAS A&M UNIVERSITY

BEFORE THE

SCIENCE POLICY TASK FORCE

OF THE

UNITED STATES HOUSE OF REPRESENTATIVES

APRIL 25, 1985

ON BEHALF OF

TEXAS ACCELERATOR CENTER

2319 TIMBERLOCH PLACE

THE WOODLANDS, TX 77380

(713) 363-0121

MR. CHAIRMAN AND MEMBERS OF THE TASK FORCE:

MY NAME IS PETER M. McINTYRE. I AM AN ASSOCIATE PROFESSOR OF PHYSICS AT TEXAS A&M UNIVERSITY AND THE SCIENTIFIC SPOKESMAN FOR THE TEXAS ACCELERATOR CENTER. I AM PLEASED TO APPEAR BEFORE THE SCIENCE POLICY TASK FORCE TODAY. I WILL DESCRIBE THE TEXAS ACCELERATOR CENTER, A MULTI-UNIVERSITY CENTER WHOSE MISSION IS TO DEVELOP NEW TECHNOLOGY FOR FUTURE ACCELERATORS. I WILL DESCRIBE THE SUCCESSFUL TESTS OF OUR SUPERFERRIC DESIGN FOR THE SUPERCONDUCTING SUPER COLLIDER. WE BELIEVE THAT THIS DESIGN OFFERS THE SIMPLEST, LOWEST COST TECHNOLOGY FOR THE SSC. I WILL ALSO HIGHLIGHT SEVERAL RECENT DEVELOPMENTS IN ACCELERATOR TECHNOLOGY AT TAC THAT ARE BEING APPLIED TO IMPORTANT PROBLEMS IN U.S. INDUSTRY.

THE TEXAS ACCELERATOR CENTER

THE TEXAS ACCELERATOR CENTER IS A NEW LABORATORY FOR ACCELERATOR PHYSICS. IT WAS CREATED IN MARCH, 1984 AS A COLLABORATION AMONG A NUMBER OF UNIVERSITIES AND LABORATORIES. ITS MISSION IS TO DEVELOP AND EVALUATE A SUPERFERRIC DESIGN FOR THE SUPERCONDUCTING SUPER COLLIDER, TO ESTABLISH A UNIVERSITY-BASED LABORATORY FOR ADVANCED ACCELERATOR R&D, AND TO TRAIN STUDENTS IN ACCELERATOR PHYSICS AND ENGINEERING.

DURING ITS FIRST YEAR OF ACTIVITY, TAC HAS DESIGNED, BUILT, AND SUCCESSFULLY TESTED SUPERFERRIC MAGNETS. THE RESULTING DESIGN APPEARS TO OFFER THE SIMPLEST, LOWEST COST DESIGN FOR THE SSC. BEYOND THE PRESENT FOCUS ON SSC DESIGN, TAC IS ALSO DEVELOPING NEW TECHNOLOGIES FOR THE ACCELERATORS OF THE FUTURE.

TAC IS A COLLABORATION OF THE FOLLOWING INSTITUTIONS:

TEXAS A&M UNIVERSITY	UNIVERSITY OF HOUSTON
RICE UNIVERSITY	UNIVERSITY OF TEXAS
UNIVERSITY OF WISCONSIN	ARGONNE NATIONAL LAB
FERMILAB	BROOKHAVEN NATIONAL LAB
LAWRENCE BERKELEY LAB	

TAC IS OPERATED BY THE HOUSTON AREA RESEARCH CENTER (HARC), UNDER CONTRACT WITH THE U.S. DEPARTMENT OF ENERGY. TAC ALSO RECEIVES STRONG INSTITUTIONAL SUPPORT FROM HARC AND FROM EACH OF THE COLLABORATING INSTITUTIONS.

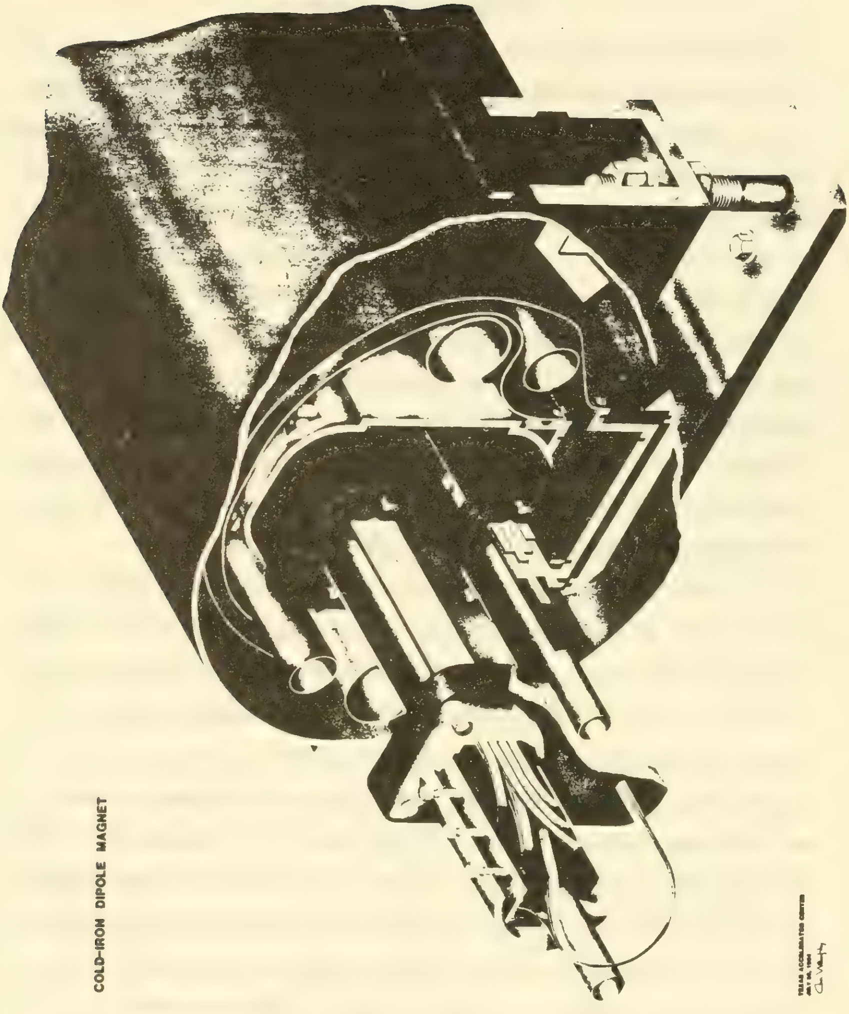
TAC IS LOCATED IN THE WOODLANDS, TEXAS, A SHORT DISTANCE NORTH OF HOUSTON. ITS FACILITIES ARE HOUSED IN A LAB AND OFFICE COMPLEX OF ~20,000 FT^2 AREA. TAC PRESENTLY HAS A TOTAL STAFF OF ABOUT 50, PLUS A NUMBER OF SHORT- AND MEDIUM-TERM VISITORS FROM PARTICIPATING INSTITUTIONS AND A NUMBER OF STUDENTS IN ENGINEERING AND PHYSICS. THE RESEARCH FACILITIES NOW INCLUDE MAGNET FABRICATION SHOPS, LIQUID HELIUM REFRIGERATOR, HIGH-CURRENT POWER SUPPLIES, AND A STATE-OF-THE-ART COMPUTER.

THE SUPERFERRIC MAGNET

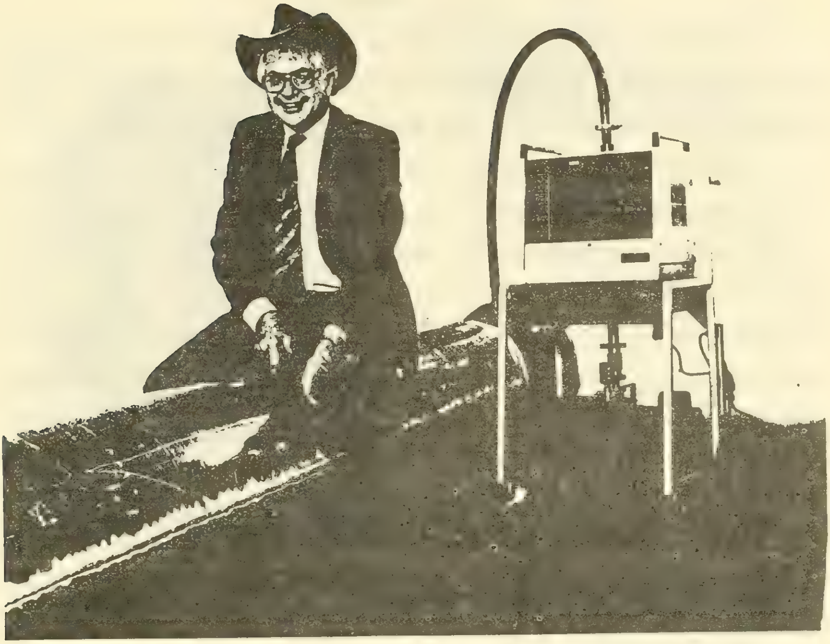
THE HEART OF THE SSC IS ITS RING OF SUPERCONDUCTING MAGNETS. THE MAGNETS ARE USED TO BEND THE BEAM OF HIGH-ENERGY PROTONS IN A CIRCULAR PATH. TAC HAS DEVELOPED A SUPERFERRIC DESIGN OF THE SSC, IN WHICH THE SUPERCONDUCTING MAGNETS ARE SPECIFICALLY OPTIMIZED FOR LOW-COST MASS PRODUCTION IN INDUSTRY. WITHIN 6 MONTHS OF ITS FIRST FEDERAL FUNDING, TAC HAD BUILT AND TESTED ITS FIRST SUPERFERRIC MAGNETS. TO DATE FOUR SHORT MAGNETS (ONE METER LONG) HAVE BEEN BUILT AND TESTED. ONE WEEK AGO TAC COMPLETED AND TESTED ITS FIRST LONG MAGNET (8 METERS LONG).* ALL MAGNETS HAVE PERFORMED TO SPECIFICATION IN ALL RESPECTS. WHILE MUCH DEVELOPMENT REMAINS BEFORE THE DESIGN IS FULLY EVALUATED, THE SUPERFERRIC MAGNET APPEARS TO OFFER A SIMPLE, LOW-COST DESIGN FOR THE SSC. TAC HAS CONTRACTED TO HAVE 3 LONG MAGNETS (35 METERS LONG) BUILT IN U.S. INDUSTRY. TESTS OF THOSE MAGNETS SHOULD BE COMPLETE BY THE END OF 1985.

THE SUPERFERRIC DESIGN IS BEING DEVELOPED IN COMPETITION WITH DESIGNS FOR HIGH-FIELD SUPERCONDUCTING MAGNETS SIMILAR TO THOSE USED IN THE TEVATRON AND HERA ACCELERATORS. THERE IS BROAD AGREEMENT THAT IT IS TECHNICALLY FEASIBLE TO BUILD THE SSC USING EITHER THE SUPERFERRIC OR THE HIGH-FIELD DESIGN. THE PRESENT R&D PROGRAM IS AIMED TO ASSESS COST AND RELIABILITY OF THE DESIGNS. IN THE SSC REFERENCE DESIGN STUDY A PRELIMINARY COST ANALYSIS WAS PERFORMED. THE COST OF THE SUPERFERRIC MAGNETS WAS EVALUATED TO BE LESS THAN HALF THAT OF THE HIGH-FIELD DESIGNS. THIS SAVING MORE THAN OUTWEIGHS THE COST OF ADDITIONAL TUNNEL CIRCUMFERENCE REQUIRED FOR A SUPERFERRIC DESIGN. THE ADDITIONAL TUNNEL CIRCUMFERENCE ALSO MAKES IT POSSIBLE TO UPGRADE THE SSC IN THE FUTURE BY ADDING A RING OF HIGH-FIELD MAGNETS. THIS COULD ENABLE US TO FURTHER INCREASE THE SSC ENERGY BY A FACTOR 3 IN THE FUTURE WITHOUT BUILDING ANOTHER NEW LABORATORY.

*THE "TECHNICIAN" SHOWN IN THE ACCOMPANYING PHOTO ADJUSTING THE FIRST LONG MAGNET AT TAC IS SHELDON L. GLASHOW OF HARVARD UNIVERSITY, 1979 NOBEL LAUREATE.



COLD-IRON DIPOLE MAGNET



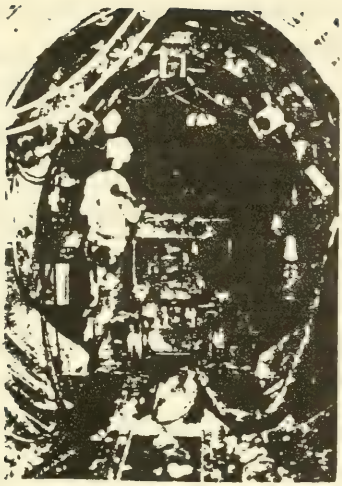
TUNNEL TECHNOLOGY

USING TODAY'S TUNNEL TECHNOLOGY, THE TUNNEL REQUIRED FOR THE SSC WOULD COST AS MUCH AS ALL ITS SUPERCONDUCTING MAGNETS. ENGINEERS AT THE TEXAS ENGINEERING EXPERIMENT STATION HAVE INVENTED A WAY TO REDUCE ITS COST.

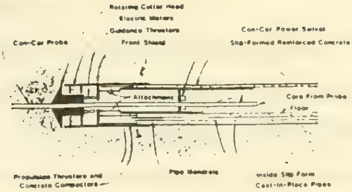
THERE ARE THREE MAIN ACTIVITIES THAT TAKE PLACE IN A TUNNELING OPERATION: CUTTING THE TUNNEL FACE, REMOVING THE MUCK, AND INSTALLING A TUNNEL LINING. THE TECHNOLOGY FOR CUTTING THE TUNNEL FACE TODAY IS CAPABLE OF PROGRESSING AT A RATE OF ~1,000 FT/DAY IN THE SOIL TYPES LIKELY TO BE TYPICAL OF AN SSC SITE. YET A TYPICAL TUNNEL PROJECT TODAY PROCEEDS AT A RATE OF ~100 FT/DAY ON A GOOD DAY! THE PERFORMANCE LIMITATION COMES FROM THE OTHER TWO STEPS - MUCK REMOVAL AND LINING INSTALLATION. BOTH STEPS REQUIRE LABOR-INTENSIVE MATERIALS HANDLING IN THE TUNNEL APERTURE. THE RESULTING LOGISTIC NIGHTMARE IS SHOWN IN PRACTICE IN FIGURE 3.

A GROUP OF CIVIL ENGINEERS AT TEES HAVE INVENTED A NOVEL METHOD BY WHICH THE MATERIALS HANDLING ACTIVITY IS REMOVED FROM THE TUNNEL BORE. THE CONTINUOUS UNITIZED TUNNELING SYSTEM (CUTS) IS SHOWN SYSTEMATICALLY IN FIGURE 3. A STANDARD TUNNEL BORING MACHINE (TBM) IS USED TO CUT THE FACE. WATER JETS ON THE CUTTING FACE SLURRY THE MUCK. THE MUCK IS COLLECTED AT THE BOTTOM AND CONTINUOUSLY PUMPED INTO A PIPELINE THAT TRANSPORTS IT ALONG THE TUNNEL TO THE LAST SURFACE PENETRATION AND OUT TO THE SURFACE. THE TUNNEL LINING IS EXTRUDED BY INJECTING QUICK-SETTING FIBER-REINFORCED CONCRETE BETWEEN INNER AND OUTER FORMS THAT MOVE CONTINUOUSLY WITH THE TBM.

THE KEY INNOVATION IN THE CUTS TECHNIQUE IS THE INCORPORATION OF THE PIPELINES FOR TRANSPORT OF MUCK AND CONCRETE MATERIALS INTO THE TUNNEL SUB-FLOOR AS SHOWN. ALL COMPONENT SYSTEMS ARE CAPABLE OF SUSTAINING A 1,000 FT/DAY ADVANCE RATE. THE CUTS SYSTEM COULD REDUCE PRESENT TUNNEL COSTS BY A FACTOR OF 2. THIS TRANSLATES INTO ENORMOUS BENEFITS TO SOCIETY FOR BUILDING SUBWAYS, AND SEWERS IN OUR CITIES. CUTS WOULD NOT HAVE BEEN DEVELOPED AT ALL WERE IT NOT FOR OUR EFFORTS FOR THE SSC.



Tunneling operation for SSC-size tunnel, present-day technology.



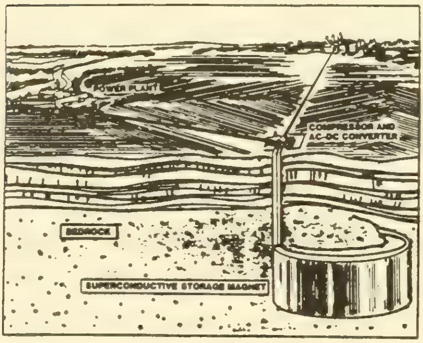
Continuous Unitized Tunneling System.

Cross-section of CUTS tunnel extrusion

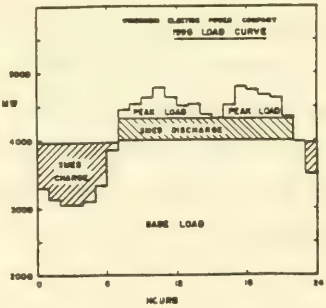
Fig. 3

SUPERCONDUCTING MAGNETIC ENERGY STORAGE

OUR COLLABORATORS AT THE APPLIED SUPERCONDUCTIVITY CENTER AT THE UNIVERSITY OF WISCONSIN HAVE PLAYED A MAJOR ROLE IN DEVELOPING A NEW TECHNIQUE FOR EFFICIENTLY AND CHEAPLY STORING ELECTRIC ENERGY. CALLED SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES), IT CONSISTS OF A LARGE COIL OF SUPERCONDUCTING CABLE SIMILAR TO THAT USED IN THE SSC MAGNETS. ELECTRIC ENERGY CAN BE STORED BY INDUCING A CURRENT TO FLOW IN THE CABLE. THE ENERGY CAN BE RECOVERED BY ELECTRONICALLY CONVERTING THE STORED CURRENT BACK INTO POWER ON THE UTILITY GRID. IN THIS WAY ENERGY PRODUCED AT NIGHT BY A UTILITY CAN BE STORED AND THEN DELIVERED TO THE GRID DURING THE DAYTIME PEAK DEMAND. RECENT STUDIES BY BECHTEL AND EBASCO INDICATE THAT SMES IS THE MOST COST-EFFECTIVE MEANS OF AUGMENTING PEAK DEMAND FOR ELECTRIC UTILITIES. ITS COST WAS REDUCED DRAMATICALLY DURING RECENT YEARS BY RESEARCH AT WISCONSIN THAT RESULTED IN AN INCREASE OF A FACTOR OF TWO IN THE CURRENT THAT CAN BE CARRIED IN A SUPERCONDUCTING CABLE. THAT WORK WAS THE DIRECT RESULT OF THE R&D ON SUPERCONDUCTING ACCELERATOR MAGNETS.



UNDERGROUND ENERGY STORAGE SYSTEM



Typical generation curve with SMES.

CONCLUSION

I HOPE THAT THE ABOVE DISCUSSION CONVEYS THE EXCITEMENT AND ACTIVITY THAT IS HAPPENING AT THE TEXAS ACCELERATOR CENTER. FOUR MORE UNIVERSITIES ARE PRESENTLY NEGOTIATING TO JOIN TAC. SEVERAL NEW TOPICS OF ACCELERATOR RESEARCH ARE UNDER CONSIDERATION. IN ADDITION TO THE STAFF OF 50, ABOUT 15 UNDERGRADUATES AND 8 GRADUATE STUDENTS ARE NOW INVOLVED IN THE RESEARCH PROGRAM. MOST OF OUR SCIENTIFIC STAFF ALSO HOLD FACULTY POSITIONS AT ONE OF THE PARTICIPATING UNIVERSITIES. WE HOPE TO DEVELOP AT TAC AN ONGOING UNIVERSITY-BASED CENTER FOR ADVANCED ACCELERATOR R&D, AND TO CONTRIBUTE SIGNIFICANTLY TO THE FUTURE OF HIGH ENERGY PHYSICS.

THE SUPERCONDUCTING SUPER COLLIDER IS AN OPPORTUNITY FOR THE U.S. TO RESUME LEADERSHIP AT THE CUTTING EDGE OF MODERN SCIENCE. THE SSC WILL GIVE US THE MEANS TO PROBE THE MOST FUNDAMENTAL BUILDING BLOCKS OF NATURE - THE QUARKS AND LEPTONS. WE HAVE TODAY A BEAUTIFUL BUT IN SOME WAYS PUZZLING PICTURE OF NATURE. ALMOST ALL THE MATTER OF OUR UNIVERSE IS LOCKED IN THE PROTONS AND NEUTRONS OF THE ATOMIC NUCLEUS. WE NOW KNOW THAT EACH OF THESE CONTAINS THREE QUARKS, LOCKED TOGETHER BY THE <u>STRONG FORCE</u>. THE QUARKS THEMSELVES WEIGH ONLY A VERY SMALL PART OF THE MASS OF THE PROTON, HOWEVER. ALMOST ALL ITS MASS, HENCE ALMOST ALL THE MASS OF THE UNIVERSE, IS LOCKED IN THE FIELD ENERGY OF THE STRONG FORCE! THE SSC WILL BE THE ESSENTIAL TOOL WITH WHICH WE CAN PROBE THE BONDS OF THE STRONG FORCE, AND SEEK TO BETTER UNDERSTAND THE SUBSTANCE OF SUBSTANCE. IN THIS QUEST WE ARE TRAINING THE BEST AND BRIGHTEST OF OUR YOUNG SCIENTISTS IN THE RICHEST CREATIVE TRADITION. ALONG THE WAY WE ARE DEVELOPING PRACTICAL TECHNOLOGIES THAT ARE OF GREAT VALUE TO OUR SOCIETY. I URGE THAT THE SSC BE BUILT AS QUICKLY AS POSSIBLE SO THAT WE CAN LEAD THE WAY IN THIS EXCITING SCIENCE. TAC IS DOING ITS UTMOST TO MINIMIZE ITS COST AND MAXIMIZE ITS BENEFIT TO THE AMERICAN PEOPLE.

THE IMPORTANCE OF UNIVERSITIES

I WISH TO STRESS THE IMPORTANCE OF UNIVERSITIES IN SCIENCE AND TECHNOLOGY IN AMERICA. IN PLANNING AND BUDGETING AT FEDERAL AGENCIES, IN TESTIMONY TO CONGRESSIONAL COMMITTEES, AND IN THE PRESS THERE IS A TENDENCY TO VIEW THE TANGIBLE STATE-OF-THE-ART FACILITIES AT OUR NATIONAL LABORATORIES AS THE CAUSE AND EFFECT IN THE PROGRESS OF SCIENCE. THIS VIEW IS DANGEROUSLY MISLEADING. WHILE MAJOR CENTRALIZED RESEARCH FACILITIES ARE OBVIOUSLY ESSENTIAL IN MANY AREAS OF RESEARCH TODAY (NOWHERE MORE SO THAN OUR OWN), NEW DISCOVERIES AND INVENTIONS COME FROM BRAINS, NOT MACHINES. OUR UNIVERSITIES BUILD BRAINS. THEY ARE THE MOST VALUABLE RESOURCE IN OUR WORLD IN BUILDING THE FUTURE FOR SCIENCE AND FOR SOCIETY AT LARGE. GREAT IDEAS COME PREDOMINANTLY FROM COMMITTED UNIVERSITY FACULTY. ALL MAJOR DISCOVERIES AT HIGH-ENERGY-PHYSICS LABORATORIES HAVE BEEN MADE USING UNIVERSITY-BUILT DETECTORS. NEW TECHNOLOGIES ARE SPAWNED MOST OFTEN IN UNIVERSITY LABORATORIES. STUDIES HAVE REPEATEDLY SHOWN THAT UNIVERSITIES PROVIDE THE MOST COST-EFFECTIVE INVESTMENT OF FEDERAL FUNDS FOR RESEARCH AND DEVELOPMENT.

IN THESE TOUGH BUDGET TIMES, I URGE THAT THE UNIVERSITIES OF AMERICA BE TREATED AS THE FIRST PRIORITY IN FEDERAL FUNDING OF RESEARCH. AS THIS SESSION OF TESTIMONY DEMONSTRATES, OUR NATIONAL LABORATORIES AND THEIR ESTIMABLE DIRECTORS CAN MOUNT A POWERFUL AND PERSUASIVE CASE FOR THE FUNDING OF THEIR PROGRAMS. THERE IS NO EQUIVALENT VOICE TO PORTRAY THE THOUSANDS OF DIVERSE AND IMPORTANT RESEARCH PROJECTS AT OUR UNIVERSITIES. I SUGGEST THAT UNIVERSITY-BASED RESEARCH DESERVES AN INCREASED SHARE OF FEDERAL RESEARCH SUPPORT, AND SOME DEGREE OF PROTECTION FROM YEAR-TO-YEAR BUDGETARY WINDS.

INTERNATIONAL COLLABORATION FOR THE SSC

Executive Summary

The SSC, a high energy proton-proton colliding beam facility, has been identified by the scientific community and governmental bodies as the next logical step in the high energy physics program of the United States in its quest toward understanding the fundamental properties of matter. The energy choice of 40 TeV in the center of mass rests on a firm intellectual basis. An international approach to the construction and operation of such a facility would build upon the existing tradition of collaboration in high energy physics and would be of great practical interest because of the magnitude of the estimated construction costs.

The United States has historically played a leading role in the important and challenging field of high energy physics. Without additional construction, the United States is expected to have by the end of this decade only three experimental interaction regions at which the highest energy collisions are available to experimenters, compared with 10 in Western Europe. Many physicists from the U.S. are already heavily involved in the utilization of the various foreign facilities and significant U.S. funds are being used to mount experiments at them. In 1990, Western Europe will have completed two of the most advanced machines in the world, while the U.S. facilities will approach the end of their useful exploitation in the 1990's. It appears essential to the continued good health of the U.S. High Energy Physics program that the construction of the next generation facility be located in the U.S.

We have considered the merits of U.S. participation in the construction of a Large Hadron Collider (LHC) in the LEP tunnel at CERN as a viable alternative to SSC construction in the U.S. Our conclusion is that the choice of this option would be the wrong decision leading to reduced energy and operational flexibility, and failing to meet the needs and opportunities of American science.

We encourage international participation in the SSC program. This includes participation in R&D, planning, design and construction of the machine proper and its major detectors, and exploitation of its physics potential. However, negotiations to this end should not delay the construction schedule. The Europeans and Japanese are already heavily committed to their existing programs and international collaboration cannot be expected to provide a major offset to the U.S. borne construction costs for the SSC unless substantial new resources beyond those presently foreseen are provided to European and/or Japanese high energy physics programs. It should be noted that the European program already runs at about twice the level, measured in terms of Gross National Product, of the American program.

The international sharing of detector equipment costs is already a well-established tradition and it is anticipated that this pattern will also apply at the SSC.

RECOMMENDATION FOR INTERNATIONAL PARTICIPATION IN THE SSC PROGRAM

We recommend that construction of the SSC should be planned, supported, and authorized within the national U.S. program. Based on such a national commitment, international participation in terms of contributions of funds, personnel, and technical components should be sought from foreign countries at all levels of R&D, design, engineering, construction and exploitation.

URA-SSC BOARD OF OVERSEERS

May 6, 1985

INTERNATIONAL COLLABORATION FOR THE SSC

I. BACKGROUND

The SSC has been identified by the scientific community and governmental bodies as the next logical step in the high energy physics program of the United States in driving further in its quest toward understanding the fundamental properties of matter. The Department of Energy is supporting the R&D phase of that undertaking, but several hurdles remain before the project can be authorized for construction. Among such issues is the extent to which international collaboration in the SSC is desirable, or in fact necessary.

The interest in international participation in the SSC is dual. The first question is financial. The current estimated construction cost for the SSC is about $3 billion FY '84 not including detector costs. Since the knowledge to be gained through the SSC is of worldwide impact, it is eminently reasonable to examine the extent to which these costs can be shared globally.

The second reason is that, traditionally, high energy physics has been and continues to be in the forefront among the sciences as a vehicle for international collaboration. Exploitation of all high energy accelerators in the western world is governed by the scientific merit of experimental proposals, irrespective of national origin of the proponents. There exist bilateral agreements for cooperation in high energy physics between the United States and Japan, China, and the USSR. Several international bodies sponsor international information exchange in high energy physics and in the development of national or regional plans for high energy facilities.

The scientific motivation for exploring fundamental particle physics at about 1 TeV collision energy for fundamental constituents of matter, quarks, gluons, and leptons, is exceedingly strong. There has been dramatic success during the last decade in identifying these constituent families and describing their interactions through theories which unify two, and even maybe three of the known fundamental forces in nature: the weak interaction, the electromagnetic interaction, and the strong interaction. While this so-called "standard model" has been highly successful, it has at the same time projected the existence of new, as yet unobserved, entities and has exhibited certain features which can only be explored in collisions of constituents in the TeV energy range. In turn, very extensive studies have shown that coverage of the conjectured region which must be explored to obtain such needed answers requires a center of mass energy in proton-proton collisions near 40 TeV at the highest luminosity that the detector permits. If this energy is reduced substantially the number of open issues subject to exploration decreases sharply, and the required luminosities may become so high as to be extremely difficult to utilize by practical detectors. For these reasons the goal to reach a 40 TeV center of mass energy rests on a firm intellectual basis.

II. SHOULD THE NEXT ACCELERATOR BE IN THE UNITED STATES?

The United States has historically played a leading role in the pursuit of high energy physics. This emphasis has been motivated by the importance and fundamental character of the field, its appropriateness as a rigorous training ground for young scientists, and its push toward the development of state-of-the-art instrumentation with applications to other areas.

Without additional construction the United States is expected to have only two front-line high energy laboratories in operation by the end of this decade: Fermilab and SLAC. Some other facilities may continue in operation to accumulate quantitative data or to pursue opportunities not now predictable. However, by the nature of the U.S. installations, the total number of interaction regions at which the highest energy collisions can be available to experimenters is only three (one at the SLC at SLAC and two at Tevatron I at Fermilab). By contrast, Western Europe will have 4 (expandable to 8) interaction points available at LEP at CERN near Geneva, 4 at HERA at DESY in Hamburg, Germany, and 2 at the $Sp\bar{p}S$ at CERN. The $Sp\bar{p}S$ is currently operating, will be upgraded, and has produced the recent discovery of the carriers of the weak interaction, the intermediate bosons, for which the 1984 Nobel Prize in Physics was awarded.

The relative magnitudes of effort among U.S., Japanese, and Europeans are illustrated in Fig. 1 which measure financially the contributions of each region expressed as a fraction of GNP.

With the increased emphasis on the importance of colliding beam facilities and the projected availability of numerous frontier facilities in Europe and Japan, there has been a substantial increase in the participation of U.S. experimentalists at foreign accelerators. This increase has been in the form of personnel involvement as well as active financial participation in several major detectors (for example, the Mark J at PETRA in Germany, L-3 at LEP at CERN, and AMY-CHAN at KEK, Japan). These activities are led by American groups. The participation of European and Japanese physicists in experiments in the United States is also very significant, and foreign participation in the construction of large and expensive detectors in the U.S. is substantial.

In 1990 Western Europe will have completed LEP and HERA, the two most advanced machines in the world. On the other hand, U.S. facilities will approach the end of their useful exploitation in the 1990's. For these reasons, the construction of a next generation facility located in the U.S. seems essential to the continued health of the U.S. High Energy Physics program, irrespective of the level of international participation in its construction or operation. The decision that the machine to fill that role should be the SSC (with parameters defined above) is based on thorough study, taking into account the state of knowledge today and in the future both of elementary particle physics and of collider technology.

III. THE ROLE OF A HADRON COLLIDER IN THE LEP TUNNEL AT CERN, GENEVA

(a) The issue

Since a very high energy proton-proton collider has been identified as the next logical step in high energy physics tools, the role of a possible hadron collider (LHC) located in the LEP tunnel needs to be discussed and related to SSC planning. Such a discussion is relevant both in respect to the LHC as a possible target of international collaboration and also as a possible comparison or alternate to the SSC in the United States. The LHC would be considerably less costly than the SSC; but, as made clear below, much of that saving is due not so much to the existence of the tunnel or the CERN infrastructure as to the much more restricted capability imposed upon the project by the tunnel.

The technical opportunities offered by placing a proton collider in the LEP tunnel have been analyzed by a European study last year in Lausanne, Switzerland, and have since been under additional study. The LEP tunnel has a circumference of 27 kilometers which is about one-fourth of that planned for the SSC. The placement of a proton collider in that tunnel would restrict the available collision energy accordingly. Roughly speaking, the single beam energy in TeV available in the LEP tunnel would be between 0.8 and 0.9 times the magnetic field measured in Tesla attained by the bending magnets.

(b) Comparison with a U.S Facility

The principal argument for the LHC is the existence of the 27-kilometer tunnel. The cost of the 90-kilometer tunnel for Design A in the Reference Design Report is about $500M (in FY '84 dollars), including ED&I and contingency. Scaling this down to 27 kilometers would give the U.S. equivalent of the LEP tunnel a value below $200M. In addition, the existence of the CERN infrastructure would reduce the required initial investment. However, the extent to which the existence of such an infrastructure should affect the site choice is, of course, also of direct relevance in considering the Fermilab alternative as one of the choices for siting the SSC in the United States. Thus, if the LHC is to be considered as a viable alternative with its drastic restriction in energy by about a factor of 3 below that of the SSC, one should compare the merits and costs of the LHC with those of an American machine sited at Fermilab with a proton-proton center of mass energy in the 10 to 15 TeV range, not with a 40 TeV SSC laboratory.

(c) Construction and Operation

The most important reason militating against placing the LHC in the tunnel also used for the LEP e^+e^- collider has to do with the realities of construction and operations. LHC construction would require corresponding LEP operational shutdowns; if such shutdowns are in any case required for reasons of fiscal stringency, one could well ask why the funds required for the LHC might not be better used for relieving such fiscal pressures.

During operation one would face the serious problem that two major colliders (LEP and LHC) are housed in a single radiological enclosure and that the detectors required for these two programs are largely incompatible. Interleaved construction and utilization of the LEP tunnel for electrons and

protons would, as a practical matter, involve costly complexities in the interaction regions. Maintenance, repair, or upgrading operations on any of the detectors or the two colliders could require shutdown of a large fraction of the world's high energy physics program.

(d) Conclusion

In general, we have strong reservations about permitting the existence of an enclosure such as a tunnel to be controlling on so important a decision as the fixing of plans for the SSC. In retrospect, there is now general agreement in the United States that although construction of the superconducting Saver and Tevatron complex has been a highly successful enterprise, it would have been a great deal more cost-effective to have constructed the superconducting ring in an independent tunnel concentric to the housing for the conventional magnet machine. The projected saving through utilization of the LEP tunnel does not appear sufficient to compensate for the serious limitation in energy and impairment of operational flexibility.

For the above reasons, including the importance to the health of the U.S. program of a next generation facility located in the U.S., we do not consider U.S. participation in the LHC construction as a viable alternative to SSC construction in the U.S., carried out either as a purely American effort or involving various degrees of international collaboration.

IV. MODALITIES OF INTERNATIONAL COLLABORATION IN RESPECT TO THE SSC

We fully support international participation in the SSC program. This includes participation in R&D, planning, design, and construction of the machine proper and its major detectors, and exploitation of its physics potential. However, negotiations toward this end should not delay the construction schedule.

We recognize that one strong motive for international collaboration is the potential reduction of cost to the U.S. government. We therefore examine the extent to which such cost reduction can be achieved during the construction and operating phases.

(a) Sharing of Construction Costs

We begin our analysis by assuming that the Japanese and West European high energy physics funding profiles remain approximately level.

In that case, the vigorous pursuit by both Europeans and Japanese of their own programs leaves few resources available for SSC construction cost sharing. Western European commitments to LEP, HERA (electron-proton collider) and their associated detectors, as well as to the upgrading of other facilities such as the Sp$\bar{p}$S will require virtually all of the assumed funding at least until 1991. As shown in Fig. 1 the European program already runs at about twice the level measured in terms of Total Gross National Product relative to the American program.

Recently, at the initiative of President Mitterand of France, international collaboration in science has become part of the Versailles Summit processes; high energy physics, with the U.S. as the leading country, has

become a subactivity under that process. Several deliberations of the West European community together with Japan under the Summit process have been held and reports on long-range plans have been issued. These activities strengthen further the international interest in high energy physics although they do not of themselves extend much hope that significant cost sharing during the construction process of the SSC is a reasonable prospect.

Japan is committed to completing its high energy e^+e^- storage ring, TRISTAN, located at KEK, Tsukuba, and to the construction of equipment to utilize the resulting collisions. A high level U.S. governmental delegation last year invited possible Japanese collaboration in the construction of the SSC, and the matter has also been discussed by several international planning bodies. It appears clear that Japanese high energy physics resources are fully committed through the TRISTAN effort for several years, and that it may take some time to solidify Japanese plans beyond that. Should such plans include participation in SSC construction, Japanese contributions would most likely be in the form of high technology components.

Comparison with the recent international participation in the construction of the HERA project at Hamburg, Germany, might be useful. Here approximately 20% of the construction funds have apparently been successfully sought from other European countries and Canada, with the expected contributions in the form of technical components. This, in turn, has led to inquiries whether German interest is well served by having some of the highest technology products procured abroad for a relatively small financial contribution. Moreover, the construction design management of the HERA facility is being made significantly more complex (and therefore costly) through the need to coordinate the design in detail with the designated foreign sources and through the reduced flexibility in choice of vendor which the prior commitment to foreign sources implies. As a result, while foreign participation in HERA has indeed been a positive step in terms of securing international recognition and commitment for the HERA project, it may not lead to a large reduction in the construction cost borne by the Germans.

This pessimistic assessment of substantial foreign resources for SSC construction could be modified if European and/or Japanese support increased to permit a collaborative construction effort, as the result of a decision by the President of the United States together with foreign chiefs of government to designate the SSC as a joint undertaking to supplement national programs, to serve as a spectacular demonstration of international amity.

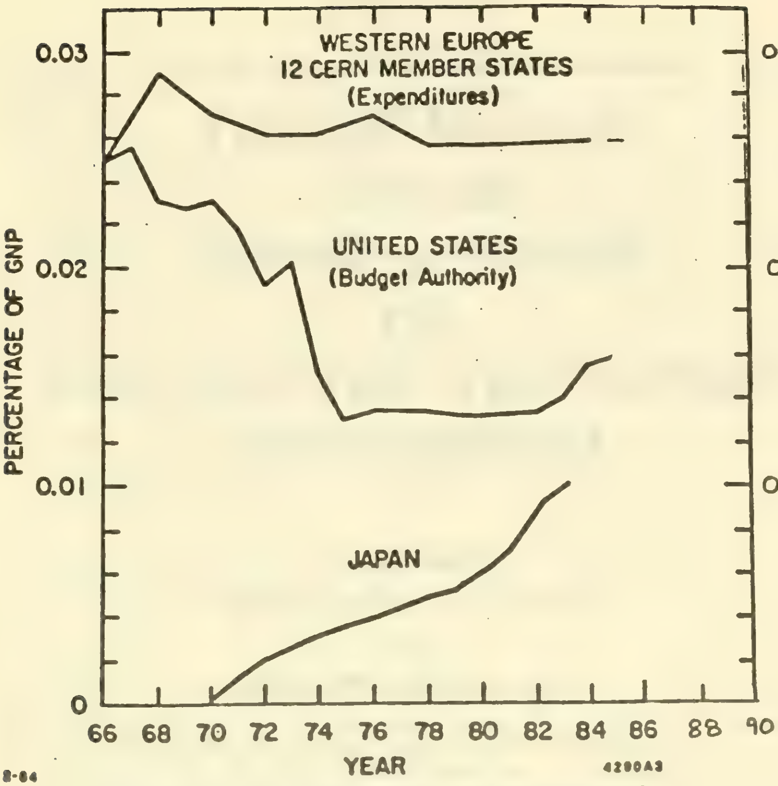
We conclude that international collaboration cannot provide a major offset to the U.S. borne construction costs for the SSC unless substantial new resources beyond those presently foreseen are provided to European and/or Japanese high energy physics programs.

(b) Sharing of Equipment Costs

It is already common practice that costs for major research equipment be shared internationally; in fact, as noted above, the U.S. has earmarked significant funds of its High Energy Physics budget to the construction of detector facilities to be used at foreign participation in the CDF detector as well as several other U.S. experimental facilities. Thus its scientific exploitation should be on a truly international basis.

V. RECOMMENDATION FOR INTERNATIONAL PARTICIPATION IN THE SSC PROGRAM

We recommend that construction of the SSC should be planned, supported, and authorized within the national U.S. program. Based on such a national commitment, international participation in terms of contributions of funds, personnel and technical components should be sought from foreign countries at all levels of R&D, design, engineering, construction, and exploitation.



Total cost of high energy physics as a percentage of GNP in Western Europe, Japan and the United States

Fig. 1

APPENDIX 4

ADDITIONAL MATERIALS FOR THE RECORD

Annual Report to the Working Group on Technology, Growth, and Employment

by the
Summit Working Group
on
High Energy Physics

April 1985

U.S. Department of Energy
Office of Energy Research
Washington, D.C. 20585

Table of Contents

INTRODUCTION

The Working Group on High Energy Physics is completing its second year of activities under the Versailles Economic Summit initiative in science and technology (see Appendix A). This report to the Summit Working Group on Technology, Growth, and Employment (TGE) documents the progress since the London Economic Summit of 1984 (see Appendix B).

High energy physics has benefitted from a long history of cooperation throughout the worldwide science community. The field has now advanced to the point where the next steps in research will likely require large expensive machines and continued and improved collaboration to use resources in the most cost-effective manner. This situation was noted by the TGE Working Group when it selected high energy physics as one of the areas of science and technology in which international collaboration could aid economic growth

> "Science and technology are a source of national and international strength and can provide immense opportunities for revitalization and growth of the world economy. They should, therefore, be given consideration in all policy decisions for national development and international cooperation.
>
> "Fundamental scientific research is one source of technological progress in industry and should be given support by governments."
>
> Report to the Williamsburg Summit
> January 1983

Upon ratification of the 1983 report by the Economic Summit leaders at Williamsburg, the member countries and the Commission of the European Communities each sent a high level political representative of their government to Washington, D.C. at the invitation of the United States, the lead country for the high energy physics Summit project (see Appendices C and D). This Working Group discussed what might be its response to the instructions from Williamsburg and agreed to meet again after completion of a study by an ad hoc group of technical experts it impaneled to identify areas of accelerator and detector technology development for near-term international collaboration. The results of the study were reported to the London Summit Moreover, the Working Group said in its report that it would organize additional subpanels before the following Summit to identify the types of facilities that will be required to continue effective progress in high energy physics (see Appendices E and F).

The London Summit of 1984 acknowledged the progress of this Working Group, along with the other Summit projects, and asked that further work be pursued and reported "to a personal representative in time for the next Economic Summit," now scheduled for Bonn in May 1985.

The activities since the London Summit have been guided by a statement of the TGE Working Group:

> "Effective cost sharing is becoming a more important element in the construction of major new facilities. Collaborative projects would benefit if coherent long-range plans for the construction and sharing of facilities in our countries were to be developed."

A meeting of the Working Group on High Energy Physics was convened in Brussels, Belgium, in July 1984, and impaneled new groups of technical experts to report on long-term planning, technical collaborations, and the identification of administrative obstacles experienced within the Summit countries that impede international collaboration. The charges to these three new groups are contained in this report under the section on the Brussels meeting.

The reports prepared by the technical experts were then reviewed at the January 1985 meeting at Cadarache, France, and the results are contained in this report under the section on the Cadarache meeting.

The Summit Working Group on High Energy Physics believes progress is being made toward cooperation among the Summit countries "in the exploration of scientific and technological development" upon which the Summit Heads of State and Government declared at Versailles "revitalization and growth of the world economy will depend--to a large extent." At Cadarache, the Group found that, since its establishment, international collaboration has increased in the use of present accelerators and in the planning for future accelerators. The Group also found that there are specific areas of technology in which near-term research cooperation is possible. Finally, the Group identified administrative regulations that hamper effective international collaboration in science and technology and that could be revised or eliminated through coordinated, high level Summit action.

The major accomplishment of the Working Group thus far has been the creation of a forum for discussions on collaboration in a major field of science by seven industrialized countries. The Group recommends the continuation of its review of long-term plans for major facilities on an intergovernmental basis.

Dr. Alvin W. Trivelpiece
Leader of the Summit Working Group on
High Energy Physics
U.S. Department of Energy

Activities
Brussels, Belgium
July 2 and 3, 1984

A meeting of the Working Group on High Energy Physics was convened in Brussels, Belgium in July 1984. At this meeting new groups of technical experts were impaneled. Areas of study of these groups were long-range planning, technical collaboration, and the identification of administrative obstacles which hamper increased scientific collaboration.

In this section we include the opening statement for the Brussels meeting presented by Dr. Alvin W. Trivelpiece, the charges to the subpanels developed at the Brussels meeting, and the listing of subpanel members for the new groups which were impaneled at the Brussels meeting. The agenda and attendees for the Brussels meeting are contained in Appendix G.

High Energy Physics Working Group Meeting
Brussels, Belgium
July 2 and 3, 1984

A. W. Trivelpiece
Opening Remarks

At the Versailles Summit meeting, some statements were made regarding the importance of cooperation in science and technology to the world economy. In particular, it was agreed that:

> "Revitalization and growth of the world economy will depend, not only on our own efforts, but also, to a large extent, upon cooperation among our countries and with other countries in the exploitation of scientific and technological development."

It was further agreed to set up a working group of representatives from the seven Summit countries and the European Commission to identify activities that would help attain these objectives. This group made recommendations in a report that was accepted by the Summit countries and reviewed at the Williamsburg Summit.

Several of the conclusions and recommendations of the Summit working group provide the basis for our meeting here in Brussels. Among them:

- "Fundamental scientific research is one source of technological progress in industry and should be given support by governments."

- "Science and technology are a source of national and international strength and can provide immense opportunities for revitalization and growth of the world economy. They should therefore be given consideration in <u>all</u> policy decisions for national development and international cooperation."

They further recommended that the Heads of State and Government "...take science and technology into account in their policy decisions and <u>continue</u> to include the subject on their agenda at future Summit meetings."

One of the areas that they recommended be considered for enhanced cooperation is high energy physics.

The report that they prepared was adopted by the Summit members and subsequently ratified by the Williamsburg Summit process. Following Williamsburg, it became clear that some response to the recommendation of the Working Group was called for. Since the U.S. was the lead country and appropriate interest at a high level in government was called for, I invited the Summit countries and the Commission of the European Communities to send a high level political representative of their government to discuss the actions that we might take to be responsive to the instructions that were both explicit and implicit from the Williamsburg Summit.

In particular, we were obliged to prepare a progress report on those activities that we decided to have carried out and to report any progress to the London Summit. Such a report was prepared. It contained a summary of our first meeting of 3, 4 October 1983 as well as the report of the technology cooperation panel we established.

One conclusion reached at the 3 October meeting was that international cooperation in high energy physics was going rather well and that no serious problems were evident.

Some of the discussion focussed on the problems associated with the fact that several of the members had programs that had long-range plans that might be in competition with one another. For this reason, it was decided at that time not to establish any technical panels to examine the question of cooperation on major future facilities.

Rather, it was decided to establish a technical subpanel to examine areas of accelerator technology that might be enhanced by increased cooperation without confronting the major facilities issue directly. This panel was chaired by Professor Richter who will describe the panel's activities and recommendations after I have finished.

The deliberations of 3 and 4 October, as well as the technical subpanels report, served as the input for the report of the Working Group on Technology, Growth and Employment to the London Summit. In this report there are two items to which I wish to call attention. One of these is Paragraph No. 22 of the report which states:

> "Effective cost sharing is becoming a more important element in the construction of major new facilities. Collaborative projects would benefit if coherent long-range plans for the construction and sharing of facilities in our countries were to be developed."

The second item in this report is the high energy physics summary page that describes the aim, activities, and outlook for this area.

In particular, it says that before the Bonn Summit next June we should organize some subpanels to identify the facilities that will be required to continue to make effective progress in this field, regardless of where the facilities are located.

This report was accepted by the London Summit. The communique issued after the Summit dealt mostly with economic concerns, but it also took special note of the progress made in the 18 areas of cooperation and "invited" the group to "...pursue further work and to report to a personal representative in time for the next economic Summit."

This is an important opportunity that is not without its risks. Many of the political leaders that I come in contact with state rather categorically that it is ridiculous to even consider duplicating major facilities in several areas of science or technology just for the purpose of scientific competition. So the risk is that unless we develop plans or programs that avoid unnecessary duplication, we may find that needed facilities may not be forthcoming anywhere. The opportunity aspect stems from the fact that the Heads of State of the Summit countries have formally recognized the important role that basic research plays in future economic development, and have asked what kind of collaboration is feasible for major facilities and some of the ancilliary aspects of their operation.

I see our task here in the next two days as one of identifying the charters for several panels that will involve representatives for the Summit countries, or others if appropriate, to do the required work and report back to this group their findings, conclusions, and recommendations. The object is not to solve these problems prior to adjournment, but to be satisfied that the necessary tasks have been commissioned. I would remind you that we should not use this forum to seek solutions to the many minor problems that crop up in the normal course of international cooperation, but rather we should focus our efforts on developing the information that will convince the Heads of State and the legislative bodies of these states that there is a rational plan or process by which high energy physics can proceed on a worldwide scale without duplication of costly facilities. I believe that it would be foolish to not take full advantage of the opportunity presented by the Summit process. I look forward to lively and constructive discussions on these subjects.

SUMMIT WORKING GROUP
on
HIGH ENERGY PHYSICS
BRUSSELS, BELGIUM
JULY 2 AND 3, 1984

CHARGES TO SUBPANELS

PREAMBLE

The Economic Summit leaders endorsed the report of the Working Group on Technology, Growth and Employment presented to them at their London meeting of June 1984. In the Communique the leaders invited the Working Group to pursue further work and to report to personal representatives in time for the next economic summit.

High energy physics has made remarkable progress over the past decades, and a significant amount of the work has been done through international collaboration. It is clear that progress in this field, dedicated to understanding the structure of matter and the forces of nature at their most fundamental level, requires major facilities that stretch technology and challenge industry, and requires more effective methods of using existing and new facilities.

To facilitate the advance of this science, three new subpanels have been created at the Brussels meeting of the High Energy Physics Summit Working Group. These subpanels are herein presented with charges to report on the implementation of paragraph 22 of the report presented to the London Summit meeting, to suggest administrative remedies in certain areas that will enhance the effectiveness of international collaboration; and to report on the status of technical collaboration between Summit nations in certain areas.

SUBPANEL FOR LONG-TERM PLANNING (Dr. H. A. Atkinson, United Kingdom, lead)

In consideration of the report of the Working Group on Technology, Growth and Employment to the London Economic Summit, the Summit Working Group on High Energy Physics has set up a subpanel to provide a forum to consider the implementation of paragraph 22 of the aforementioned report in respect to the field of High Energy Physics (HEP). Paragraph 22 reads as follows:

> "Effective cost-sharing is becoming a more important element in the construction of major new facilities. Collaborative projects would benefit if coherent long-term plans for the construction and sharing of facilities in our countries were to be developed."

The subpanel will be provided by the Summit nations with their plans and proposals for high energy physics, and with progress reports on existing major facilities. They will also take account of plans for high energy physics worldwide.

Although it is important to proceed in as timely a manner as possible, it must be recognized that the production of such plans will take time and that, by the nature of high energy physics which is driven by scientific need and technological advance, plans will develop and change as time goes on. The subpanel will report periodically to the Working Group on HEP on such coherent long-term plans.

SUBPANEL ON TECHNICAL COLLABORATION (Dr. D. G. Stairs, Canada, lead)

In consideration of the technical recommendations of the Subpanel on Improving International Collaboration in High Energy Physics (February 1984) accepted at Brussels, the Summit Working Group on High Energy Physics created a new subpanel to review the activities that are underway or planned to carry out such recommendations.

SUBPANEL ON ADMINISTRATIVE ISSUES (Dr. P. Fasella, European Communities, lead)

In consideration of administrative issues raised by the Subpanel on Improving Collaboration in High Energy Physics (February 1984) the Summit Working Group on High Energy Physics created a new subpanel to address issues in three areas:

1. CUSTOMS

The field of high energy physics involves experiments in which there is extensive collaboration in the design, construction and sharing of complicated and expensive apparatus. In most cases a detector or a similar item may include pieces of the apparatus from several countries that are assembled into a complete system, which, in turn, is then shipped to another country for use in an experiment. This procedure is now being applied to accelerator construction.

In some cases, taxes or tariffs on some piece of the system may be charged or the duty-free use may be restricted to a specific period of time. This situation represents a serious impediment to the kinds of scientific exchanges encouraged by the Summit process, as endorsed by the Heads of State. The duty-free, extended-time transfer of scientific apparatus or components from one nation to another would substantially improve the ability of high energy physicists to effectively and economically conduct their experiments.

CHARGE: Each Head of Delegation shall be responsible to appoint an individual to determine the nature of the problems covered by present customs practices. This fact-finding activity should be summarized in a brief report to the European Communities' designee, who, in turn, has the lead responsibility for preparing a report to the Summit Working Group on High Energy Physics. This report should identify the problems and make recommendations for solutions to these problems.

2. DATA COMMUNICATIONS

Improved data transmission facilities are of great importance in furthering the aim of the Summit Group to expand and improve international collaboration in science. Data transmission rates of 10 kilo-baud to mega-baud are required for the transmission of text, programs, program output, graphics and data. Networks exist within individual countries and between certain countries; but there appear to be barriers to cost-effective international communications arising from national telecommunication policies. For example, a recent attempt to institute a network between Europe and the United States was unsuccessful.

If these barriers were to be overcome, the benefit to science would be great in that individual groups could function more effectively in international collaboration from their home base in all phases of their work, from preparing proposals through running an experiment to the analysis of results.

To improve the existing situation it is necessary to analyze the data transmission requirements as a function of bandwidth, and to determine the technical and institutional barriers to more effective communications. Accordingly, a working group is to be established with the charge to:

1. Estimate the international traffic requirements at various bandwidths over the next decade.

2. Summarize the barriers to cost-effective computer-to-computer communications from:

   a. Technical factors

   b. Economic factors

   c. National telecommunication policies

3. Suggest methods to improve the present situation.

3. PERSONNEL EXCHANGES

High Energy Physics is already an activity with a highly developed international aspect: nationals of one country often work in another on both short-term and long-term bases. This can cause problems associated with visas and with work permits, including work permits for family members. There can also be serious social problems which restrict mobility of personnel. High energy physics has had experience with these problems over a long period, but it is inevitable that they will arise in other scientific activities as these become increasingly international in character.

To facilitate mobility among scientific and technical personnel, it would be desirable if summit nations could reduce or remove social and legal barriers. The Summit Working Group on High Energy Physics therefore proposes that a panel be convened to investigate and document the type and extent of such problems and to recommend how they could be solved. For example, one possibility would be to accord special status to cover collaborative scientific work.

The Panel should be composed of technical experts from the Summit nations suitably advised by members of the high energy physics community with direct experience with these problems.

The head of each delegation will appoint one delegate to the subpanel on planning and one for technical collaboration. He will appoint three delegates from the subpanel on administrative issues, one for each issue. The names of the delgates will be made known to the leader of the Summit Working Group on High Energy Physics and to the appropriate subpanel leader by August 1, 1984. The delegate may be accompained by one or two advisers from his nation at meetings of his particular subpanel. The first reports from the subpanels are due to the leader of the Summit Working Group on HEP no later than January 1, 1985. This Working Group has set aside the days of January 12, 13 and 14, 1985 for a meeting in France to review these reports, as necessary.

Summit Working Group
High Energy Physics
Subpanel Members

Long-Term Planning:

United Kingdom:	Dr. H. H. Atkinson (Chairman) Director, Science Science and Engineering Research Council
Canada:	Professor J. D. Prentice Department of Physics University of Toronto
European Communities:	Professor H. Schopper Director-General of CERN
	Dr. J. Sacton ECFA - Chairman Universite Libre de Bruxelles
France:	M. Pierre Lehmann Directeur, Scientific de Physique Nucleaire et Corpusculaire du CNRS
Germany:	Professor Volker Soergel Chairman of the DESY Directorate Deutsches Elektronen-Synchrotron (DESY)
Italy:	Dr. Nicola Cabibbo President National Institute of Nuclear Physics (INFN)
Japan:	Professor Yorikiyo Nagashima Faculty of Science Osaka University
United Kingdom:	Dr. Derek Colley Physics Department Birmingham University
United States:	Dr. Jack Sandweiss (Principal Member) Department of Physics Yale University
	Dr. Leon Lederman Director Fermi National Accelerator Laboratory

United States: (Continued)	Professor Burton Richter Director Stanford Linear Accelerator Center
	Professor Maury Tigner URA SSC Central Design Group Lawrence Berkeley Laboratory

Technical Collaboration:

	Dr. D. G. Stairs (Chairman) Department of Physics McGill University
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European Communities:	Dr. G. Brianti CERN
	Dr. E. Lillestol Department of Physics University of Bergen
France:	M. Joao Meyer DPHPE CEN-Saclay
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United States:	Mr. Paul J. Reardon Associate Director, High Energy Facilities Brookhaven National Laboratory

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United States:	Dr. Bernard Hildebrand Chief of Physics Research Office of Energy Research U.S. Department of Energy

Activities
Cadarache, France
January 1985

A meeting of the Working Group on High Energy Physics was convened in Cadarache, France in January 1985. The Group reviewed the reports of its three subpanels on long-range planning, technical collaboration, and the identification of administrative obstacles which hamper increased scientific collaboration.

The Group found that, since its establishment, international collaboration has increased in the use of present accelerators and in the planning for future accelerators. The Group also found that there are specific areas of technology in which near-term research cooperation is possible, and they identified administrative regulations which hamper effective international collaboration in science and technology that could be revised or eliminated through coordinated, high level Summit action.

In this section, we include the Report of the Working Group on High Energy Physics from the January 1985 meeting and the reports from the Working Group subpanels. The agenda and attendees for the Cadarache meeting are contained in Appendix H.

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Report of the High Energy Physics Working Group from the
January 1985 Cadarache Meeting for the
Versailles Summit Working Group on Technology, Growth, and Employment
for the May 1985 Bonn Economic Summit

EXECUTIVE SUMMARY

In July 1984 the High Energy Physics Working Group met in Brussels primarily to develop a response to paragraph 22 of the Versailles Working Group "Technology, Growth, and Employment" report to the 1984 London Summit:

> "22. Effective cost sharing is becoming a more important element in the construction of major new facilities. Collaborative projects would benefit if coherent long term plans for the construction and sharing of facilities in our countries were to be developed."

At Brussels the High Energy Physics Working Group established three study groups to report on:

1. Long-Term Planning,
2. Technical Collaboration, and
3. Administrative Obstacles to International Scientific and Technical Collaboration.

The High Energy Physics Working Group met again in January 1985 at Cadarache to review the reports of these study groups and to make recommendations based on them as might be appropriate. The complete reports of the Study Groups follow this Executive Summary.

The main objective of high energy physics research is to discover what are the fundamental constituents of matter and the physical laws that govern their interaction. This field of research is in a revolutionary epoch in its pursuit of this goal. The great advances in this field that have taken place over the last ten years have required the use of major facilities involving particle accelerators and large collaborative teams of scientists and engineers.

These accelerator centers are located at several places around the world and each of them has made key contributions to the advances in understanding in this field developed over the past decade.

While the main objective of high energy physics research is fundamental knowledge, the technology which is developed by the scientists and engineers in high energy physics research is impressive and finds significant application in other areas of science and in industry. Thus, for example, developments in the technology of particle accelerators have found application in synchrotron light sources and pulsed neutron sources for

other areas of science; in radiation sources for cancer therapy; and in ion implantation accelerators for materials modification and for production of integrated circuit chips. The development of superconducting cable and magnets has found application in magnetic fusion research and in the rapidly growing area of nuclear magnetic resonance imaging in the medical field. The push for increasingly sophisticated high energy physics detectors and data analysis capability has stimulated technology developments in many areas of science and industry. All of these examples illustrate the truth of the statement from the Report of the Williamsburg Summit:

> "Fundamental scientific research is one source of technological progress in industry and should be given support by governments."

A. LONG TERM PLANNING

1. Although accelerators have become more and more sophisticated, world expenditure on high energy physics over the past decade has remained roughly constant. This has been achieved by closing less productive accelerators, by using new technological concepts, and by increased international cooperation. Scientific productivity has thus increased dramatically.

2. Many fundamental questions in high energy physics remain to be solved. Some should be resolved by the next generation of accelerators now under construction: the Tevatron[1] (U.S., to begin operation in 1986), TRISTAN (Japan 1986), Stanford Linear Collider (U.S., 1986), Large Electron-Positron collider (CERN, 1988), and Hadron-Elektron-Ring-Anlage (F. R. Germany, 1990). These accelerators are designed to explore different fundamental questions and, as such, are complementary and not duplicative. For Europe, funds are committed to 1990.

3. However, one clear need has recently emerged which cannot be met by the present generation of accelerators. This is the requirement to extend the energy range of hadron colliders. The most advanced plan for doing so is the U.S. effort towards a Superconducting Super Collider (SSC). In parallel, European scientists are considering various options for collisions of protons with protons or antiprotons, making use of the LEP tunnel and other infrastructure at CERN. Facilities envisaged for addressing other open questions are a large linear collider for electron-positron collisions and an electron-proton collider which could also make use of the LEP tunnel. Japan is exploring future options after the completion of TRISTAN.

4. It is not realistic to expect detailed plans beyond this stage, because further projects in this science-driven field must depend on the results from the accelerators now under construction and on the development of new accelerator concepts. In any case, high energy physics can only expect continued support if the quality of its science continues to justify it.

5. The Working Group believes that the required new and advanced facilities can be built and operated within broadly constant worldwide budgets (with some fluctuations during years of peak capital expenditure), provided that there is no unnecessary duplication. This implies planning on an interregional basis to ensure complementarity and cost effectiveness. Further concentration of facilities is inevitable; however, the Working Group is convinced that more than one region working effectively in high energy physics is essential to the health of the science in the period of the study.

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[1]See Appendix I for a brief summary of the key features of some of the principal accelerators now under construction.

6. Regarding utilization, ways must be devised of encouraging increased participation by scientists of all countries that would like to share in this world community activity. The limited number of unique facilities must remain open to competent scientists from all over the world.

7. It is of the greatest importance to continue the discussion and planning on an intergovernmental level, so that the objectives envisaged here can be implemented in an orderly, cost-effective way.

B. TECHNICAL COLLABORATION

Progress in exploring the frontiers of high energy physics has, in the past, critically depended upon the construction of progressively more complex and larger particle accelerators and detectors. This has required the continued investment in development of new technology to make these facilities possible, both technically and financially. With the facilities that can be foreseen to be needed in the future, this investment in new technology, in international collaboration in this development, and in interaction with industry becomes even more important. The following observations and recommended activities would help to foster such increased interaction if carried out.

1. All nations should further encourage the already active international collaboration in accelerator technology in order to:

i) develop known technologies to a stage where they can be incorporated in high energy physics facilities in a cost-effective way; and

ii) encourage a broad program to develop new accelerating methods. For this purpose existing large facilities (e.g. large lasers) should be made available for experiments to test new ideas. A certain fraction of the support going into high energy physics should continue to be used for long-term developments.

Similar efforts should be made to develop new methods of particle detection.

2. As accelerator and detector systems become larger and more complex, it is vitally important to work to common international standards in order to reduce costs and ensure compatibility of equipment. It is recommended that such standards be pursued at national and international levels in collaboration with industry. Areas of special importance are associated with data acquisition and analysis systems and superconducting wires for magnets. Successful examples from the past are CAMAC and FASTBUS instrumentation standards.

3. Existing high energy physics laboratories are centers of advanced knowledge in many technological fields and operate in an environment of wide international cooperation. It is recommended that ways and means be found to increase the use of them for the training and education of scientists, engineers, and other technical staff from industrial firms, universities, and other institutions for the mutual benefit of all concerned.

C. ADMINISTRATIVE OBSTACLES TO INTERNATIONAL SCIENTIFIC AND TECHNICAL COLLABORATION

It is clear that the removal of certain administrative obstacles would greatly improve and facilitate international cooperation in several areas of science and technology such as physics and fusion.

The Working Group believes that, because enhanced international collaboration implies cost sharing and cross participation in the construction and exploitation of regional devices, new administrative procedures are imperative. Many of the present procedures are serious obstacles to effective cooperation.

More specifically, the High Energy Physics Working Group recommends that attention should be given to the following:

1. Cross participation in projects through the provision of scientific equipment and components for major facilities (e.g., detectors) is currently hampered by the fact that tariff and tax exemptions are only provided for short durations that are not compatible with the time frame of the collaboration, which may last for more than 10 years.

2. The exchange of scientific and technical staff is an important factor in international collaboration. Increased collaboration can become a reality only if the responsible authorities create conditions suitable for the free exchange of scientific staff. There are several such conditions, notably:

i) to simplify the administrative admission formalities in the host country;

ii) to facilitate integration of the research worker and his family in the host country; and

iii) to guarantee adequate social coverage.

3. Data transmission is an important aspect of the work of the high energy physics community. The acceptance of cross participation in facilities, which are widely separated geographically, relies heavily on

inexpensive and efficient data transmission. Two aspects have been singled out by the Working Group for urgent consideration within the Versailles Working Group on Technology, Growth, and Employment framework:

i) the review of the charging policy for scientific data transmission across borders; and

ii) the promotion of effective data communication standards in order to ensure compatibility.

The Working Group recommends to the Versailles Working Group on Technology, Growth, and Employment that a study be conducted on this subject subsequent to the Bonn Summit and that a report on the steps that might be taken to improve conditions related to the above-mentioned administrative impediments to effective cooperation be submitted to the subsequent Economic Summit.

D. SUMMARY RECOMMENDATION

The High Energy Physics Working Group, which was established in response to the Versailles Working Group on Technology, Growth, and Employment has proven to be a useful forum to discuss certain aspects of international cooperation in this field that have not been previously examined at the intergovernmental level.

Therefore, it is proposed that the High Energy Physics Working Group should continue for the time being and make a further progress report on long-term planning, technical collaboration, and administrative obstacles to the 1986 Summit.

REPORT OF THE LONG TERM PLANNING SUBPANEL OF THE VERSAILLES WORKING GROUP (VWG) ON HIGH ENERGY PHYSICS

Preamble

This is an interim report to the Versailles Working Group (VWG)/High Energy Physics Panel in response to paragraph 22 of the report of the VWG to the Economic Summit meeting in London in June 1984. We cover the status and future of the discipline up to the year 2000. The membership of the subpanel, and a note on the accelerators referred to, are attached.

Success of HEP

High energy physics is in a revolutionary epoch in its quest for an understanding of the structure and working of the physical universe. Comparable turning points in physics have taken place only twice in this century with the theory of relativity and quantum mechanics. A remarkably successful synthesis is emerging, based upon a microstructure of fundamental particles and forces. These concepts are now perceived to be essential to the cosmological models of the evolution of the universe. The subject continues to be recognized by its Nobel Awards and the participation of gifted young practitioners worldwide. One of the ingredients in the success of the subject is its variety of scientific tools, particle accelerators and detectors, which have made possible the collection and sharing of relevant data.

The present strong base of scientific understanding has given an unusually clear view of the open questions. Examples of these are the origin of mass, the structure of the fundamental particles, and the possibilities for grand unification of the forces of nature. Some of these questions will be investigated with the facilities now under construction, but others demand observations at much higher energy. A clear resolution of these deep questions will require a variety of accelerators over the period under review.

Costs and Funding

In the past decades, facilities in the different regions have been both duplicative and complementary. History tells that duplication has often been profitable, two similar machines eventually evolving in quite different directions. Another feature is that machines have grown increasingly complex and, as a consequence, there has been an increasing centralization and sharing. Time and again, still productive but lower energy facilities have been shut down to release resources for new activities. In this way, the overall funding in high energy physics has been relatively constant, averaged over the past decade, yet the capability of the machines exploiting new technological concepts has increased dramatically.

For the future, a new generation of facilities beyond those now under construction is required to address many of the open scientific questions. These machines will be expensive. We believe that the required facilities can be built and operated within broadly constant budgets (with some brief excursions during years of peak capital expenditure) provided that there is no duplication of major facilities. This implies planning on an inter-regional basis to ensure complementarity and cost-effective decision making. Further concentration of facilities will probably be needed; however, we are convinced that more than one region working effectively in high energy physics is essential to the health of the science in the period of our study.

Facilities Under Construction

High energy physics is a rapidly developing science and, therefore, it would not be sensible to have a rigid plan to the year 2000. The physics that will be done in the late 1980s and early 1990s has largely been determined by decisions already taken. Thus, now under construction are the Tevatron (U.S. to begin operation in 1986), TRISTAN (Japan, 1986), SLC (U.S., 1986), LEP (CERN, 1988), and HERA (Germany, 1990). These machines are largely complementary. They involve a substantial commitment of funds through to the 1990s in Europe and the mid- to late-1980s in the U.S. and in Japan.

Future Facilities

We have mentioned the open scientific issues and that some of these will be addressed by the machines now under construction. Nevertheless, in view of the long lead times, designs for the following generation of machines are being actively drawn up to pursue this quest. These are modulated by the scientific needs and by technical possibilities within the boundaries of strong economic constraints. There is a close cooperation between the scientists and engineers in all countries concerned in refining the plans and in carrying out the necessary R&D work. Increasing inter-regional collaboration is particularly apparent in the construction of particle detectors that have become a major item in the total cost of new facilities.

One clear need that emerges from the present understanding of physics is the requirement to extend the energy range of hadron colliders. The collision energy must be raised to the level which permits a significant exploration of the mass scale for new particles and interactions. Most advanced in this direction, is the R&D stage of the USA effort towards a Superconducting Super Collider (SSC). In parallel, European scientists are considering various options for collisions of protons with protons or anti-protons, making use of the LEP tunnel and other infrastructure at CERN. Other possibilities for addressing the open questions are a large linear collider for electron-positron collisions and an electron-proton collider which could also make use of the LEP tunnel. Japan is in the process of

making a study of their future options after the completion of TRISTAN. Finally, we note that there is worldwide collaborative R&D on novel accelerator concepts; however, these are unlikely to come to fruition before 2000.

Future Scenarios

A number of scenarios are possible to the year 2000. It is too early to select the strategy which will satisfy the scientific needs in the most cost-effective manner. However, common to each scenario is the further complementary development in different regions. In the U.S. a decision is expected in the late 1980s regarding a major new accelerator (i.e., the SSC). In Europe, no major new commitment could be made before 1990.

Involvement of Other Regions and Countries

In the interests of minimizing costs and maximizing scientific results, an ever increasing degree of collaboration among all regions will be needed. A key objective will be to stimulate maximum participation of the scientists and engineers of all regions in the planning, eventual construction, and use of new facilities. In the matter of utilization, continued encouragement should be given to participation by the USSR, the People's Republic of China, and, indeed, by scientists of all countries that would like to share in this world community activity. The limited number of unique facilities must remain open to competent scientists from all over the world.

Tasks for Intergovernmental Group

We believe that it is of the greatest importance to continue the discussion and planning on an intergovernmental level. It would be our hope that as studies proceed, succeeding reports of this or a similar intergovernmental group will develop a long-range plan so that the objectives envisaged here can be gradually implemented in an orderly, cost-effective way. Progress within the resources which can reasonably be provided by our Governments will depend on a continuing reassessment of the state of the science concerned.

H. H. ATKINSON
Lead for the Subpanel on Long-Term Planning
10 December 1984 (including subsequent revisions to 7 February 1985)

Summit Working Group
High Energy Physics
Subpanel Members

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	Dr. J. Sacton Chairman, ECFA Universite Libre de Bruxelles
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	Dr. Leon Lederman Director Fermi National Accelerator Laboratory

United States: (continued)	Professor Burton Richter* Director Stanford Linear Accelerator Center
	Professor Maury Tigner URA SSC Central Design Group Lawrence Berkeley Laboratory

The Subpanel met on 12/13 November 1984 in Abingdon, England.

*Professor Richter was unable to attend the meeting.

PARTICLE ACCELERATORS NOW UNDER CONSTRUCTION OR STUDY

Tevatron I	Photon-antiproton collider; 1 + 1 TeV; under construction at the Fermi National Accelerator Laboratory, U.S.; first operation for physics estimated at the end of 1986 or early 1987; superconducting magnets; two experimental areas; detector approved (so far): CDF.
TRISTAN	Electron-positron collider; 30 + 30 GeV; under construction at KEK, Japan; first operation for physics estimated in 1986; four experimental areas; detectors approved (so far): VENUS (Japan), TOPAZ (Japan), and AMY (international collaboration).
SLC	Stanford Linear Collider; colliding electrons and positrons; 50 + 50 GeV; under construction at Stanford, U.S.; first operation for physics estimated at the end of 1986 or early 1987; one experimental area; detectros approved: PEP Mark II (starting 1987), and SLD (starting about 1990).
LEP	Large Electron-Positron collider; initially 50 + 50 GeV, increasing to 100 + 100 GeV; under construction at CERN, Geneva; first operation for physics is estimated at the end of 1988 or early 1989; 27 km circumference synchrotron; initially four experimental areas; detectors approved: ALEPH, DELPHI, OPAL, and L3.
HERA	Electron-proton collider; 30 + 820 GeV; under construction at DESY, Hamburg; first operation for physics estimated in 1990; 6.3 km circumference synchrotron; superconducting magnets; four experimental areas.
SSC	Superconducting Super Collider; at reference design stage; hadron beam collider (protons with either protons or antiprotons); 20 + 20 TeV; synchrotron circumferences ranging from 90 to 164 km depending on magnetic field strength; superconducting magnets; could be operational in 1993-94.

International Collaboration in Accelerator and Detector Development
Report of the Technical Subpanel of the Summit Working Group on High Energy Physics

Introduction

The Summit Working Group on High Energy Physics established three Subpanels at a meeting held in Brussels on July 1 and 3, 1984. The Subpanel on Technical Collaboration was asked to review the current status of international collaboration in important areas of accelerator and detector research and development. This document describes the findings and recommendations of the Subpanel. The basis for the review of technical collaboration was provided by a report entitled "Improving International Collaboration in High Energy Physics" by Professor B. Richter et al., (February 1984). That report was submitted to the Working Group at the Brussels meeting.

The membership of the Subpanel on Technical Collaboration, which included six members of the Richter Committee, was:

David M. Binnie	Imperial College (United Kingdom)
Ewart Blackmore	TRIUMF (Canada)
Giorgio Brianti	CERN (European Community)
Donatus Degele	DESY (Federal Republic of Germany)
Kunitaka Kondo	University of Tsukuba (Japan)
Egil Lillestøl	University of Bergen (Norway) and CERN (European Community)
Joao Meyer	CEN-Saclay (France)
Paul J. Reardon	Brookhaven National Laboratory (U.S.)
Douglas G. Stairs	McGill University (Canada), Chairman
Sergio Tazzari	INFN, Frascati (Italy)
John J. Thresher	Rutherford Appleton Laboratory (United Kingdom)
Gustav-A. Voss	DESY (Federal Republic of Germany)

Status of Technical Collaboration

The status of technical collaboration in accelerator and detector R&D is outlined in Attachments I and II, respectively. The subject matter encompassed by these attachments is defined by recommendations 4 through 17 of the Richter Committee (see Appendix F).

While the central thrust of high energy physics is fundamental research, the subject exploits and stimulates many diverse aspects of advanced technology. The scale of experiments and facilities is such that this technology involves collaboration not only between the universities and the large laboratories but also with a wide range of industries. The tradition of collaboration is so well established that even between laboratories proposing competitive projects one finds much collaboration on

technical problems of accelerator design and construction. Personal contacts are of key importance in the establishment of international collaboration in accelerator science and detector development. Such contacts form naturally through existing mechanisms among the older physicists, but much could be done to foster contacts for younger scientists entering the field. The opportunity to establish contacts with industry is especially important for the latter group.

Of the many specific areas of collaboration identified by the Richter Committee, some have already reached a level of maturity where they are widely applied in other fields. We have found it particularly helpful to examine points where collaboration with industry is just beginning. The benefits to industry in terms of improved capabilities in precision manufacturing and advanced technology have been clearly documented by a study at CERN[1]. We note that developments in our areas of R&D often occur through the realization by physicists that techniques already available in advanced industries can be adapted for high energy physics. The Subpanel has identified laboratory/industry collaboration as an extremely important benefit of research in high energy physics for both sides.

It is clear that key ideas spring from many sources and that small, possibly isolated groups need support; indeed at present we find more ideas than can be well supported. The long term future of this field depends on promising ideas for particle acceleration and detection. We, therefore, strongly endorse international collaboration in these topics.

Superconducting Magnets and Cryogenics

In the last half year the Reference Designs Study for the SSC has been completed in the U.S., while in Europe a feasibility study for a hadron collider in the LEP tunnel has been carried out. In the Federal Republic of Germany the HERA project at DESY, based on international collaboration, is under way. A brief account of the work in progress in the various countries/regions appears in Attachment I.

For the above studies, the collaboration on design, beam dynamics, and technical assessment is already good and can be further enhanced by, for example, collaborative utilization of test and measuring facilities and other activities aimed at avoiding unnecessary duplication of efforts. The other recommendations of the Richter Committee, pertaining to this area, remain valid.

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[1]"Study of the Economic Utility of CERN Contracts," H. Schmeid, CERN 75-6.

New Methods of Particle Acceleration

This field is in very rapid expansion; good progress is being made and already some of the proposed schemes appear to give promise of achieving, in due time, the performance required for reaching very high energies. Scientific work in this field has great potential for technical development and for training high energy accelerator builders at national laboratories and universities. Research and development on new accelerator techniques is still carried out in the "parallel" mode (as defined by the Richter Committee). However, close international collaboration in R&D work at the national and regional levels should be encouraged. Such collaboration should include the exchange of personnel in accelerator physics, and in related areas, and agreements to make existing facilities available on an international basis.

Detector Research and Development

International collaboration in detector R&D is already the normal mode of operation in high energy physics, and many excellent examples of this work can be found. Three recommendations were made by the Richter Committee to improve these efforts and two of these are to be addressed by the subpanel on administrative issues. The remaining recommendation urged the strengthening of home-based programs to derive the maximum benefit from these collaborations in terms of technology transfer and training of students. The recommendations would be a significant step in achieving this goal. Further suggestions are made in Attachment II.

The development of electronics and data acquisition equipment, such as NIM and CAMAC for high energy physics research, represents an excellent example of collaboration and technology transfer with industry. These components have found widespread use in other fields such as the medical diagnostics. Recently several developments in detector research have led to collaborations with industry in the production of components. Some of these are described in Attachment II and recommendations are made to improve specific problem areas.

RECOMMENDATIONS

The Subpanel recognizes the importance and value of interntional collaboration as it exists today. For the long term, we recommend an even stronger degree of collaboration between the laboratories themselves and their industrial partners. In particular, we recommend the following specific actions:

1. Provide the ways and means to support a broader international program in advanced accelerator and detector studies to bring promising developments to a stage where serious consideration can be given to their incorporation in the next generation of high energy physics facilities;

2. The existing laboratories are centers of long-standing and successful international activity. The Subpanel recommends that these laboratories be used to provide a broadly-based program of training and education in a collaborative international environment. This should be implemented by special means such as fellowships aimed at scientists, engineers, and other technical staff from industrial firms, universities, and technical institutions whose main interests lie outside high energy physics; and

3. As accelerator and detector systems used for high energy physics become larger and more complex, industrial skills have had to be applied to resolve many of the technical, manufacturing, and construction problems. In such applications it is vitally important to work to common international standards. It is recommended that these be pursued at national and international levels in collaboration with industry. Areas of special importance are associated with the computer industry, data-acquisition systems, superconducting wire technology, and cryogenic magnet construction.

Attachment I

ACCELERATOR RESEARCH AND DEVELOPMENT

A. Superconducting Magnets and Cryogenics

U.S.

In the U.S. significant progress has occurred in the initiation of the design phase for the SSC. A Central Design Group has been established at the Lawrence Berkeley Laboratory (LBL) with two regional centers at Fermilab and Brookhaven National aboratory (BNL). Studies are under way of specific topics such as aperture requirements, beam dynamics, particle tracking, and selection criteria for superconducting magnets. The organization and staffing of the Central Design Group for the SSC project is proceeding. In some of the SSC workshops international participation on key problems has been encouraged and fostered.

Research and development for the magnet and cryogenic systems is in progress in four laboratories [BNL, LBL, Fermilab, and the Texas Accelerator Center (TAC)]. Prototype magnets are being constructed for operation at fields of 3, 5, and 6.5 T. A final choice of the SSC magnet will be made within a year. So far the models of the BNL/LBL, TAC, and Fermilab approaches have been tested with quite satisfactory results. As part of these activities, efforts are being pursued towards better NbTi conductors and improved winding/construction techniques, aimed at lowering costs and minimizing magnetization effects due to persistent currents. The development of higher field magnets using Nb_3Sn continues at BNL in collaboration with LBL. This work has potential importance for dipole and high gradient SSC applications. In the area of superconducting wire development, worldwide approaches are being examined and industrial involvement in superconducting magnet construction, already a fact in Europe, is being examined.

EUROPE

The development of superconducting magnets for the proton ring of HERA at DESY is being carried out in close collaboration with industry. Dipole fields of 6 T have been reached with NbTi conductors at 4.5° K. The construction of four prototype magnets, 9 m in length with cold iron, has just been entrusted to industry. Collaborations among several countries are being set up for the prototype production in industry. Personnel from Fermilab, BNL, and other U.S. and European laboratories are heavily involved in project design reviews.

In addition to this, a number of national laboratories and institutes are forming a collaboration, initiated by CERN, to promote technological developments directed towards the construction of magnets at higher field

levels (8 to 10 T) suitable for a future hadron collider.* Two possible lines of development concern:

i) the utilization of Nb_3Sn conductor at 4.5° K with enhanced current density and small effective filament diameter (to minimize magnetization currents at injection); and

ii) the use of the best NbTi conductor (with possible additions) at 2° K (superfluid He).

The former implies a substantial conductor development taking advantage of the considerable work already done for fusion, while the latter depends on the assessment of extended cryogenic systems at 2° K and on the design of reasonably simple cryostats. Experts from the various laboratories are preparing a global technical program. The participating institutes will work in conjunction with industry and use existing test and measuring facilities.

JAPAN

Development of magnets suitable for future hadron colliders is under way at KEK in collaboration with industry. In addition to a 5 T magnet, work is in progress along two lines already mentioned for Europe. A multishell dipole wound with Nb^3Sn conductor has reached high fields (8 - 10 T) and the development of superconducting quadrupoles is in progress.

B. Superconducting Radio Frequency Cavities

At the second workshop on radiofrequency superconductivity which was held at CERN in July 1984, 80 participants from 26 institutions (Australia, Brazil, Europe, Japan, and the U.S.) reviewed the present status of the field.

At DESY, work is concentrated on two nine-cell cavities at 1 GHz to be installed in PETRA. A three-cell cavity at 500 MHz has been tested successfully in the TRISTAN accumulation ring at KEK.

It appears that after many years of development in a number of laboratories, often through international collaboration, the technology has advanced to the point that large scale applications are being considered at CERN to increase the beam energy of LEP beyond 55 GeV and at DESY for HERA.

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*European Laboratories involved in the development of accelerator superconducting magnets: Technical University of Vienna (Austria); CEN-Saclay and CEN-Grenoble (France); DESY and KFK (Federal Republic of Germany); INFN and ENEA (Italy); NIKHEF and ECN (Netherlands); CERN; SIN (Switzerland); RAL (United Kingdom)

The results obtained so far give confidence that large systems could operate at accelerating fields of at least 5 MeV/m. The next step to be undertaken is the production of such structures in industry.

In other institutes (Wuppertal and Cornell Universities) development work is under way to obtain higher field gradients and quality factors, suitable for large linear electron accelerators.

C. New Methods of Particle Acceleration

On the very important issue of new techniques for particle acceleration, an international workshop entitled "High Fields for Particle Acceleration" was held in Frascati, in September 1984, under the sponsorship of the CERN Accelerator School, the European Committee for Future Accelerators (ECFA), and the Italian Institute for Nuclear Physics (INFN). About 80 participants from all regions in the disciplines of accelerator, high energy, and plama physics reviewed the problems connected with various approaches to the design of very high energy linear colliders to be operated at accelerating and/or focusing fields about one order of magnitude higher than those at present achievable. Needed beam parameters were defined; information on the peculiar characteristics and unresolved problems of the various proposed acceleration schemes was exchanged, and the major technical issues were brought into focus.

Major experimental programs under way at various laboratories were presented in the fields of short wavelength, normal linacs driven by very high power sources (SLAC, Novosibirsk, KEK) and two-beam accelerators [DESY, LBL, Lawrence Livermore National Laboratory (LLNL)]. New experiments are being set up or planned on other promising approaches, such as beat-wave accelerators and near-field devices (BNL, RAL, Cornell, and various other universities). Theoretical work on these and other more exotic schemes was also extensively discussed at the workshops.

D. Accelerator Schools

In the U.S., a summer school in accelerator physics and design has been held for the past four years. In Europe, CERN has set up a school in accelerator physics, which started in October 1983 with a two-week specialized course on proton-antiproton colliders. In September 1984, a two-week general course, attended by 150 students, was held in Orsay (France). The school has also organized and partly sponsored two international workshops on High Fields for Particle Acceleration and on Non-linear Dynamics. Scientists from most European institutes contribute to the formulation of the school programs and to its organization. Close contact and collaboration are maintained with the U.S. Accelerator School and participation in both the U.S. and European courses is on an interregional basis.

Attachment II

DETECTOR RESEARCH AND DEVELOPMENT

A. Training in Detector Technology

Existing collaborations in detector development have shown that it is possible for small university groups, as well as the larger national laboratories, to make significant contributions. Two problems are noted:

1. Frequently new detector techniques are developed to the point where a solution exists for a particular problem. Then time, personnel, and money constraints dictate that detector construction must start and potentially interesting development studies cease. Some mechanism for transferring this development to the university environment would be welcomed;

2. The size and sophistication of present detectors mean that the time scale for such experiments may be inappropriate for the Ph.D. student entering near the beginning of the project if the student is to present a conventional thesis based on analysis of results. Universities should be encouraged to use detector design and development or research in new methods of detection as part of the Ph.D. program. In addition there are opportunities for persons from other disciplines such as electrical engineering, chemistry, materials research, and solid state physics in this work.

An initiative which could be considered is the establishment of detector physics schools in the same manner as the existing accelerator physics schools. These would be aimed primarily at young physicists and technicians/engineers.

B. Collaboration with Industry

The high energy physics program in Japan has had an excellent history of collaboration with industrial firms in the development and construction of components for detectors. Some examples are the construction of the large superconducting solenoid for the CDF detector at Fermilab, the production of lead glass for the OPAL detector, scintillating glass for photon detectors, and the production of a variety of other photosensitive devices. Japanese industry is also playing an important role in the construction of the large central detectors for the TRISTAN experiments. In Europe and the U.S., industry also is involved in the construction of large detectors.

The scale, both in quantity and size, of the components for the next generation of detector systems requires industrial participation, and other nations are following Japan's lead. Several typical examples of this

collaboration are mentioned below. In the following two sections, two developments involving the electronics industry are discussed in more detail. A very important result of these developments is that applications for the work are frequently found outside of high energy physics.

1. Superconducting Magnets

The superconducting coil for the DELPHI detector at LEP is the responsibility of the Rutherford Appleton Laboratory in the U.K. This will be one of the largest superconducting magnets in the world. Contracts have been awarded to industrial firms in a number of different countries for the construction of components for this magnet; namely, Germany, France, Switzerland, and Italy. CEN-Saclay has the responsibility for the ALEPH coil, the construction of which is entrusted to industry on a similar basis.

2. Scintillating Plastic Fibres

Development of scintillating plastic fibres to be used in detectors for high energy physics was started in the USA and France. Such fibres are to be used both in high density calorimeters (DELPHI, UA1) and in high resolution track detectors. This development has led to the setting up of a French industry with the intention of producing optical plastic fibres for short range data transmission.

3. Bismuth Germanate Crystals

Monocrystals of bismuth germanium oxide (BGO) are being developed in a worldwide collaboration to be used in the L3 detector at LEP. Production lines have been set up in China and France to cover the needs of L3. Physicists are studying BGO crystals for their special semiconductor properties, which in turn may lead to other applications.

C. Solid State Detectors, Charge Transport Devices, and VLSI

Techniques used by the electronics industry in the manufacture of high density integrated circuits are now being applied to the production of high-spatial-precision particle detectors. Two examples are:

1. the silicon microstrip device based on reverse-biased diodes implanted in microstrips on silicon wafers; and

2. the charge-coupled device (CCD) used in TV cameras and by astronomers as photon detectors.

Both devices are being developed in collaboration between industry and high energy physics groups in the U.S. and Europe. Prototypes based on silicon and gallium-arsenide substrates are being developed for the charge-coupled device.

The possibilities for groups and smaller industries to participate in such developments are limited by access to computer-aided design facilities and by the cost and time needed for the production of integrated circuit prototypes. These problems may be overcome by:

1. organizing the access to one or several CAD-CAM facilities at major laboratories; and

2. the creation of facilities for the production of circuits.

An example of such a coordination is NORCHIP for the Scandinavian countries.

D. Data Acquisition and Data Processing

Future high energy physics experiments are characterized by enormous complexities and data rates. In order to cope with both the complex architectures and data flows, involving communications between large numbers of microprocessors and minicomputers, a new standard FASTBUS is being developed in cooperation between Europe and the U.S. FASTBUS is replacing the CAMAC standard and is expected to be widely used outside high energy physics. For the moment only very few industrial firms are engaged in the development of the FASTBUS standard and the building of FASTBUS electronics. A stronger cooperation with industry should be encouraged. The online and offline data processing of future experiments require an order of magnitude increase in available computer power. In order to solve this problem, emulators of big mainframe computers are being built, again with worldwide cooperation. These developments could have an impact on the future needs for and use of computers, also outside the high energy physics community. In some areas where industrial development is progressing rapidly, as in the optical laser disk for high density storage, the high energy physics community will have to choose or impose a standard.

E. Access to Rare or Costly Detector Components

With the construction of very large detectors for colliding beam experiments and for neutrino studies there is occasionally need for special materials which are both rare and costly. Examples are: uranium for calorimeters; and heavy water, gallium, and indium for solar neutrino detectors. The needed material is often borrowed from one country to be used at a high energy physics laboratory in another country for the duration of the experiment. Such temporary transfer of material is often very problematic. We, therefore, strongly recommend that a policy be developed for international use of such materials.

Acknowledgment

We thank Professor Walter Hoogland for the facilities and hospitality of NIKHEF.

ADMINISTRATIVE OBSTACLES TO INTERNATIONAL SCIENTIFIC AND TECHNICAL COOPERATION

International cooperation in scientific research and technological development must be considered increasingly as a fundamental component of world economic growth and for that reason deserves special attention from the highest authorities.

Although in most sectors the need to cooperate arises spontaneously between research workers, the development of cooperation, on the other hand, requires the presence of optimum conditions which, in most cases, only governmental authorities are capable of creating.

This is particularly true at administrative level, where numerous obstacles hinder, in particular, freedom of trade in scientific and technical equipment and instruments and exchanges of research personnel, both research workers and technicians, or of scientific and technical information. The national and international regulations, most of them laid down several decades ago, are no longer in keeping with modern technological development and, in the present case, form barriers that should be removed or at least lowered in order to make possible and encourage expansion in international scientific and technical cooperation.

The working parties on High-Energy Physics and Controlled Thermonuclear Fusion set up after the Summit meeting of Heads of State and Government held in Williamsburg, USA, in May 1983 considered that these obstacles should be especially examined in order to determine and to suggest ways and means of by-passing them.

This report is the result of that examination with respect to the two areas concerned.

1. Transfer in scientific and technical equipment and instruments

1.1. Present situation

The conditions governing the international transfer of scientific and technical equipment and instruments vary from one country to another and depend as a general rule on the duration of the transfer, the type of equipment involved and its intended use.

In most of the countries[1] which participated in the Summit, temporary importation is a relatively simple matter, but the periods of validity are limited to a maximum of two or three years, which is incompatible in certain cases with the time required to carry out complex scientific experiments. Such importation generally enjoys total or partial exemption from taxes or if a declaration has been made to the effect that the item in question is to be re-exported (the case in Japan). The formalities to be completed in order to obtain such exemption are sometimes quite complex, and should normally take only a relatively short time (say a week), but in complex cases may take longer. However, it requires quite a complex administration and in many cases it is totally impossible to give evidence of identity with respect to each instrument after the completion of the "temporary" use. Here again the existing rules are not at all in keeping with the complexity of international HEP-cooperation.

Permanent importation of scientific and technical equipment is generally subject to the rules of the Florence Convention (1952). In the case of most of the countries which participated in the Summit, specialized scientific equipment can be imported free of tax provided that it is to be used by public research bodies or bodies recognized as such, for non-commercial purposes and that equipment of equivalent scientific value is not currently produced in the importing country (or in case of the EEC Member States, in the EC). Depending on the country, components of such equipment may not enjoy the same conditions, which can lead to difficulty where repairs have to be carried out (the case in the USA and Japan).

Exportation of such scientific and technical equipment and instruments is not, as a general rule, subject to special restrictions. It should, however, be noted that the equipment in question often falls within the category of strategic and high-technology products, particularly in the two areas in question, trade in which is at present strictly supervised (particularly in the USA and Canada) ; where equipment of this type is concerned, restrictions are encountered which necessitate cumbersome formalities that may last for several months.

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1 The word Country has been used for simplicity but it should be taken to mean customs territory possibly made of several countries (e.g. EEC)

1.2. Existing forms of international cooperation

The case of CERN (Centre Européen de Recherche Nucléaire - European Nuclear Research Centre) in the field of High-Energy Physics and that of JET (Joint European Torus) in the field of fusion provide interesting examples with regard to trade in scientific and technical equipment and instruments between several countries.

The European Economic Community possesses a Community Regulation dated 28 March 1983[2] relating to the duty-free admission of scientific instruments or apparatus intended "for either public establishments principally engaged in education or scientific research and those departments of public establishments which are principally engaged in education or scientific research" on condition that they have been approved by the competent authorities of the Member States to receive such articles duty-free and "to the extent that instruments or apparatus of equivalent scientific value are not being manufactured in the Community". The regulation requires the European Commission to deal with applications within three months, but pending decision, the competent authority may authorize importation of the instrument or apparatus which is the subject of the application. It has to be noted, however, that the Community regulations give very sophisticated definitions of "a scientific instrument or apparatus" and that these definitions are interpreted very restrictively by the authorities, so that the practical importance of this exception is at present not very great in international HEP.

Scientific equipments or apparatus imported in this way into the Community from other countries are, as a general rule, subject to value added tax ; derogations from that rule may, however, be permitted on the basis of bilateral agreement, each case being dealt with individually.

At all events, scientific and technical equipment and instruments sent as gifts, in token of friendship or goodwill "by an official body, public authority or group carrying on an activity in the public interest which is located in a country other than the Member State of importation, to an official body, public authority or group carrying on an activity in the public interest which is located in the Member State of importation and approved by the competent authorities to receive such goods exempt from tax" are exempt from VAT (Council Directive 83/181/EEC of 28 March 1983). Discussions are under way with a view to extending this exemption to equipment and instruments benefitting from the temporary admission system (see proposal for the 17th Council Directive, in respect of which the European Parliament has already expressed a favourable opinion).

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2 O.J. L 105, April 4, 1983 83/918/EEC

As regards CERN, it is exempt, as an intergovernmental organization, from the payment of customs duties and taxes, and it benefits from preferential customs procedures. In thus directly imports (into Switzerland or France) equipment for its own use in accordance with the rules governing its special status. This includes the experimental equipment which remains the property of institutes that cooperate with CERN ; in this case, temporary importation is not required. CERN also exports directly (from Switzerland or France) whatever the reason for the exportation may be. Apart from the two host States, CERN has obtained preferential agreements concerning the temporary importation of equipment that belongs to it into the United Kingdom and Italy.

For JET, an agreement has been established between this common enterprise and the United Kingdom which gives it advantages equal to these of CERN.

1.3. Possible improvements

The cases of CERN and JET are examples of potential improvements to the system currently in force.
Among possible solutions, consideration can be given to taking steps at ministerial level to accord a special status to scientific and technical equipment and instruments which would enable them, within the framework of intergovernmental agreements governing the projects that resulted from the Versailles Summit, to be moved freely between the laboratories participating in the "Controlled Thermonuclear Fusion" and "High-Energy Physics" projects. Awaiting this solution the following measures should be taken :

- Extension of maximum time for temporary use to 10 years,
- Granting of status of "scientific equipment" for all equipment exclusively used in HEP-research,
- Facilitation of procedures to give evidence of identity after temporary use".

It should also be noted that a draft European agreement aimed at facilitating the movement of scientific research equipment between the Member States of the Council of Europe is being studied and that, in this regard, the Ministerial Conference of 17 September 1984 recommended that consideration should be given to whether such an agreement would be of advantage. The agreement will be based on the application of Article 13 of the Customs Convention, itself based on the Florence Convention relating to the importation of scientific equipment, under which minimum facilities are provided for. The negotiation of this new agreement, however, will have to be conducted so as to ensure that it does not hinder application of greater facilities that certain contracting parties grant or might grant, either by means of

unilateral provisions or under bilateral or multilateral agreements of the same type as those previously mentioned. (As regards this point, reference may be made, in particular, to the EC Council Directives already being implemented or at the stage of preparation). Subsequently, consideration could be given to extending such an agreement to non-European countries, and in particular to the countries which participated in the Summit.

It will be the task of TGE working group to make a statement upon the practicalities of setting up and operating such an agreement or Conventions.

2. Exchanges of scientific and technical staff

2.1. Present situation

The mobility of research workers has for several years been a matter of concern to those responsible for national scientific and technological policies, at least in Europe. Many studies have been conducted (Council of Europe, EEC, European Science Foundation) and the conclusions are relatively unanimous : such mobility can become a reality only if the responsible authorities create conditions suitable for the free exchange of scientific staff.

There are three such conditions :

- to simplify the administrative admission formalities in the host country (as regards both the research worker and his family) (visas) ;

- to facilitate integration of the research worker and his family in the host country (accommodation, motor car, work permit for the spouse, children's education) ;

- to guarantee social coverage equivalent to that in the country of origin (social security, pension rights, return to the country of origin).

2.1.1) Administrative formalities

These formalities are relatively simple in most cases.

Temporary visas can generally be granted and even extended (sometimes, however, with a certain amount of difficulty in this regard in the USA), without major problems, in particular if the research workers are covered by a diplomatic agreement or an alliance treaty, if responsibility for them is accepted by international companies or organizations (the case in the USA), or if they can show that they are engaged in highly intellectual activities in the arts or sciences (the case in Japan). The families of the research workers generally enjoy the same facilities. It should, however, be noted that, in certain cases, the research workers and their families lose their citizenship rights both in the host country and in the country of origin.

2.1.2) Integration in the host country

The problems of integration in the host country depend to a large extent on the host laboratory and on its administrative services. In certain cases, the formalities are simplified by bilateral agreements that exist between laboratories (the case in Canada and Italy). In most cases, however, the research workers and their families are subject to the normal rules of the host country.

The conditions relating to accommodation vary considerably from one State to another and even from one town to another ; certain research centres possess accommodation in which the families may stay temporarily, but, in most cases, the research worker is obliged to find accommodation for himself. Likewise, as regards driving licences, road taxes and vehicle registration, the research worker is obliged to complete the normal formalities with which every foreigner arriving in a new country has to cope, even if the visit is for a limited period.

As regards the spouse's work permit, obtaining one is generally a lengthy and difficult process (except within the EEC in the case of nationals of its Member States).
Many problems also arise, particularly during short-term stays, with regard to children's education[2], since mother-tongue instruction is not available and there is no point in the children's acquiring diplomas which are not recognized in their country of origin.

2.1.3) Social coverage

Where social coverage is concerned, although the social-security rules of the host country are generally applicable to a guest research worker and his family, it is mainly the country of origin which is responsible for facilitating that person's return to his mother country so that the period he spent abroad does not adversely affect his career prospects and his pension rights. Generally speaking, a research worker who works for some time in a foreign laboratory does not contribute to the national pension and social security systems of its own country while he is abroad and thus loses his social entitlements unless this question is specifically draft with in bilateral totalization agreements or in multilateral agreements (the case of EEC member states). If he returns to his original employment, he could also lose his right to promote and his career prospects sufer in consequence.

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2 At the European level (JET in particular) this question has been solved by creating European Schools with a special status

2.2. Existing forms of international cooperation

The situation at CERN is sufficiently typical to be referred to here as an example in this respect. Almost half the scientific and technical personnel are from foreign laboratories and stay in Geneva for periods of varying length. Most of these research workers are seconded provisionally from their home laboratories and administrative responsibility for some of them is assumed by CERN, but most of them remain administratively attached to their original laboratories ; the problem of their status is thus minimized to a large extent and, after their stay at CERN, the research workers resume work in their home laboratories and their careers generally suffer no adverse effects as a result of their temporary secondment.

In all cases in which a residence permit is issued (activity on behalf of CERN must account for at least 50% of the holder's time), the research worker can be accompanied by his family. In the case of certain persons who are nationals of countries which are not members of CERN, a visa may be necessary to enable them to enter Swiss or French territory, but this requirement gives rise to only a few minor problems.

There is generally no difficulty in obtaining a work permit for spouses, but the situation on the labour market in the Geneva area is relatively depressed at present.

Where children's education is concerned, things are made easier by the international setting of Geneva, but problems do exist in respect of recognition of diplomas. Difficulty is also encountered with regard to accommodation, since the number of apartments available in Geneva is relatively small, but CERN rents some apartments which it can place at the disposal of new arrivals for a limited period.

Within the European Community, moreover, the administrative formalities are simplified, since the question of visas and work permits does not arise. It may, of course, arise in the case of research workers who are nationals of non-Community countries[3].

The problems that remain to be solved are those of the research worker's status and of the conditions under which he returns to his country of origin ; no uniform status exists and there is no framework agreement between the Member States of the Community to settle these questions, which consequently are dealt with under bilateral or multilateral agreements between the parties concerned. This is the case, in particular, with the agreement on the promotion and mobility of staff in the field of Thermonuclear Fusion, concluded by all the European States which are

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3 This is not the case for JET, third countries (Switzerland, Sweden) having the same advantages as Community Member States

participating in that programme and the European Community. Under that agreement, each party to it is prepared to receive staff seconded from the other parties for the purpose of participating in implementation of the joint project, and the Commission of the European Communities assumes responsibility for expenditure arising from the secondment of such staff (travelling, allowances, etc...).The contract of employment between the seconded staff and their original employers remains in force throughout the period of secondment ; likewise, the original employer ensures that the social coverage of his seconded staff continues. The host organization places its equipment, social services and other facilities at the disposal of the seconded staff.

It should also be noted that the European Economic Community proposed, in the context of its activities for the purpose of stimulating cooperation and scientific and technical exchanges at European level, that it support a number of ancillary measures intended to contribute to promoting the mobility of scientific personnel within the Community (transport, career, information, etc...).

2.3. Proposed solutions

From the examples referred to above, it can be seen that one of the best ways of setting up a satisfactory system of mobility for research workers[4], without creating problems concerning subsequent employment, is to base the system on secondment from a research institute or body in the country of origin to a research institute or body in the host country. In this connection, the agreement between the European countries on the joint programme on Controlled Thermonuclear Fusion could form a basis on which an international agreement between the countries which participated in the Summit could be concluded. That same agreement could provide that the secondment expenditure would be shared between the research worker's home laboratory and the host body, and that the latter would undertake to facilitate the integration of the seconded research worker and his family by placing accommodation at his disposal, even if only for a limited period.
Other problems, such as those connected with taxes, children's education, equivalence of diplomas and work permits for spouses require lengthy and difficult negotiations before they can be solved, and such negotiations could be initiated forthwith. It should be noted in this regard that the Council of Europe was assigned by the Ministerial Conference of 17 September 1984 the task of examining, in accordance with normal procedures and in

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4 In this document we have referred to the case of experienced research workers ; the mobility of young research workers, particularly during their first employment, gives rise to different problems and should doubtless be examined in greater detail

cooperation with the competent national authorities, measures to improve the mobility of research workers in Europe. This could lead to measures that might be taken within the broader framework of Summit cooperation.

Whilst such measures are awaited it would in any case be useful to inform potentially mobil researchers of their rights, and the facilities offered by the various laboratories collaborating in the HEP and fusion fields.

It will be also the task of TGE working group to give its opinion upon the practicalities of setting up and operating such an agreement cr convention.

3. Exchange of scientific and technical data[5]

3.1. Present situation

The present situation in Europe is described in the ECFA (European Committee for Future Accelerators) Report ECFA/83/75 and references to a more detailed description of the requirements can be found there. The modes of communication which are needed include :

- The transmission of text either as electronic mail or long documents

- The transmission of program files to ensure software standardization, with updating, on a project

- Remote terminal access and remote job submission to certain computer facilities

- The transmission of technical data in graphical form

- The transmission of data from experiments. This is of particular importance for fault diagnosis during the data-taking phase of an experiment

- Tele-conferencing. The efficient management of large collaborative enterprises requires frequent exchange of information and views leading to decisions on policy and design.

The HEP community undertakes its research in international collaborations which span the continents. European groups make extensive use of the facilities in North America such as SLAC (near San Francisco) and Fermilab (near Chicago). Groups from Canada, Japan and the US (and other nations) participate in experiments undertaken at the European Laboratories, such as CERN and DESY. The greater distances separating those involved in the large intercontinental collaborations characteristic of High Energy Physics make good communication facilities essential.

The exchange of scientific and technical information in high-technology sectors such as Controlled Thermonuclear Fusion or High-Energy Physics is, like trade in scientific and technical equipment or the mobility of research workers, a prerequisite for the success of research in these fields. The removal of obstacles to such an exchange, however, depends on the preparedness of the

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5 The terme "scientific and technical data" means solely the raw results of scientific and technical experiments and never the communications and publications that result from such experiments. The dissemination of knowledge by those means gives rise to another, more general, problem which is not dealt with in this report

parties concerned to communicate information which, in certain cases, can be of commercial value or can be the subject of important scientific communications.

Apart from that prerequisite, there are still many obstacles, whether at technical level, in view of the large number of data to be transmitted and the difficulties associated with the interconnection of communications networks, at economic level, in view of the rates charged by the companies responsible for transmission, or even at political level, in view of the fact that it is high technologies that are involved here and certain information may be covered by military or industrial secrecy.

3.1.1) Technical obstacles

Intensive use of information technologies for the transmission and processing of scientific and technical data has been an important step in the rise of scientific research and, in sectors such as High-Energy Physics or Controlled Thermonuclear Fusion, these technologies are an indispensable instrument without which progress would be impossible.

In the case of High-Energy Physics, telecommunications networks making use of private or public cables at present offer only limited possibilities with regard to transmission speeds (9 600 bits/sec) and there are very few intercontinental lines. In the near future (1 1/2 years), it seems that six to eight lines between Europe and the USA and one line between Japan and the USA, all restricted to 9 600 bits/sec, would be necessary in order to meet the physicists'requirements.

In two or three years, it will doubtless be necessary to set up two lines capable of transmitting at the rate of 56 kbits/sec and to add eight to ten lines between Europe and the USA and one line between Japan and the USA (all capable of transmitting 9 600 bits/sec). Subsequently, most of the 9 600 bits/sec lines would have to be converted to 56 kbits/sec. For the time being, there seems to be no urgent need to set up 1 Mbits/sec links ; nonetheless, in view of the forecasts made by the High-Energy Physics laboratories for the end of the decade, it can be estimated that the largest countries might need one hour per day at 2 Mbits/sec via satellite.

Two-way communications across the North Atlantic and the North Pacific could also turn out to be necessary.

The technical obstacle does not arise so much from the available capacity or number of lines, since technical knowledge and resources are such that industry should be able to cope with the requirements sketched out above, as from the compatibility and interconnection of existing networks ; the most difficult

problem to overcome is probably the absence of a complete set of international standards in this field, both with regard to the interface of means of telecommunication and to the software used. In particular, the network access protocols would have to be standardized or at least harmonized.

The ESPRIT programme, put in hand within the framework of the EEC, should make it possible to solve some of these problems in the short term, particularly those which concern compatibility of equipment and software in the different European countries[6]. The question will arise once again in the case of exchanges between European, American and Japanese laboratories. An experiment on the on-line transmission of data via a commercial telephone cable is, however, under way as a cooperative project undertaken by Fermilab and the University of Tsukuba.

The purpose of a further experiment will be to link via satellite the data base of the Information Centre of the Nagoya Plasma-Physics Institute with an equivalent data base in the USA. It will be noted on this point that the potential of satellite transmission is very high and should provide increasingly better and cheaper means of communication. Encouragement should be given at this time to exploring the ways by which the scientific community can take advantage of the new economies brought about by these new technologies and, therefore, the broadest set of potential options should be reflected in the planning.

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6 It should also be noted that the Commission of the European Communities intends to implement a large-scale programme of action for the balanced development at European level of the telecommunication sector, the objective of which, inter alia, is to place at the users' disposal, under the best possible cost and time conditions, the equipment and services most likely to meet their future requirements

3.1.2) Economical Obstacles

Making use of public data transmission networks, as things stand at present, is often the only solution available to laboratories and research bodies that wish to exchange information.

In particular, where High-Energy Physics is concerned : "in France, there is a lot of networking activity in the laboratories of the Paris region, from where previously installed permanent connections exist to different locations in France and to CERN ; there is also a permanent connection between Annecy and CERN. In Germany, it may be noted that an important new project has been started under the name DFN (Deutsches Forschungsnetz) with the aim of providing high-level services over the DATEX-P public network. In Italy, there does not exist yet a public data network ; various laboratories of the INFN (Istituto Nazionale di Fisica Nucleare) are linked by a private DECNET network, which has a connection to CERNET. In Switzerland, the public network is fairly new and is still missing some international connections. In the United Kingdom, besides the public PSS network, there exists a very important private network operated by the Computer Board, JANET (Joint Academic Network) ; it is derived from the network previously operated by the Science and Engineering Research Council, SERCNET ; JANET is connected to PSS and to some computers at CERN. There is also a permanent connection between the Rutherford Appleton Laboratory and the DESY Laboratory.

The possibility of connection to American networks, including ARPANET, BITNET, TELENET and TYMNET, has been surveyed. Apart from what is offered by most of the European public networks, i.e. essentially access to TELENET and TYMNET with gateways to other networks, some more information is available on a direct connection between ARPANET and SERCNET and on CSNET, a new project of the American National Science Foundation.

Connections also exist between the European networks and DATAPAC (Canada) and VENUS-P (Japan). Contacts are being established with the HEP groups in these countries"[7].

In the field of Controlled Thermonuclear Fusion, laboratories and research centres make use in most cases of the same public networks, but it has been noted that the private links between research centres are less developed than in the case of High-Energy Physics. This is probably due to the fact that, in this field, on-line data processing is not required to the same extent.

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7 ECFA/83/75, September 1983

This use of public data transmission networks, in view of the rates charged by the PTTs, gives rise to considerable expenditure, particularly in the case of High-Energy Physics. In this regard, it would doubtless be advisable to activate negotiations with the PTTs in order to obtain preferential rates or the allocation of special lines. With regard, in particular, to international links, it would be necessary, on the one hand, for the PTTs to charge rates comparable to those applicable at national level and, on the other hand, for them to authorize free interconnection of the networks reserved for scientific and technical users. It should be noted that several studies have been undertaken within the European framework with a view to defining the characteristics of a high-speed European network in cooperation either with private firms or with the PTT administrations. Pending completion of such projects, the interconnection of all the X 25 national networks would be of primary importance.

3.1.3) Political obstacles

The political obstacles are real, but probably less difficult to surmount, particularly in the field of High-Energy Physics, where the results are hardly likely to be covered by military or industrial secrecy. Where Fusion is concerned, close scientific and technical cooperation derives from a declared political will to ensure that participants exchange the most important scientific and technical information relating to this sector. (In this connection, if an agreement between the countries which participated in the Summit is to be concluded in this field, it would be advisable to incorporate in it a clause concerning the dissemination of results).

3.2. Requirements for the coming decade :

On bandwidth :

1. The HEP community in Europe requires in two or three years access to public data networks at medium (56 Kbps) and, by the end of the decade, high (IMbps) bandwidths with international links able to operate at the high bandwidth.

2. The average total international traffic generated at medium bandwidths is 250 K bits/second during the working week. The high bandwidth traffic could reach 2 Megabits/second at the end of the decade when new accelerators are in full operation in Europe and the US.

Technical barriers :

3. It is essential that rapid agreement is reached on ISO standards for communications.

4. Manufacturers must be strongly encouraged to support these standards as they are agreed, by setting public sector procurement requirements, if necessary.

Cost factors :

5. An "academic discount" should be given for the use of computer communication services by the academic community.

6. International tariffs should be set at a level much closer to those for national services.

PTT factors :

7. Full international interconnection of all national public data networks is essential.

8. Until recommendations (1) and (6), in particular, are satisfied, the interconnection of international leased lines for academic use should be permitted without restriction or additional charge.

4. Conclusions

It is clear that the removal of certain administrative obstacles would greatly improve and facilitate international cooperation in several areas of science and technology. Because enhanced international collaboration implies cost sharing and cross participation in the construction and exploitation of regional devices, new administrative procedures are imperative, many of the present procedures being serious obstacles to effective cooperation.

More specifically, the HEP and Fusion Working Groups having examined this report at their Cadarache meeting on January 13 to 16 recommend that attention should be given to the following questions :

a) Cross participation in projects through the provision of scientific equipment and components for major facilities is currently hampered by the fact that tariff and tax exemptions are only provided for short durations that are not compatible with the time frame of the collaboration, which may last for more than 10 years.

b) The exchange of scientific and technical staff is an important factor in international collaboration. Increased collaboration can become a reality only if the responsible authorities create conditions suitable for the easy exchange of scientific staff.

There are several such conditions, notably :

- to simplify the administrative admission formalities in the host country ;
- to facilitate integration of the research worker and his family in the host country ;
- to guarantee adequate social coverage.

c) Data transmission is an important aspect of the work of the HEP and Fusion Communities. The acceptance of cross participation in facilities, which are widely separated geographically, relies heavily on inexpensive and efficient data transmission. Two aspects have been singled out for urgent consideration within the Versailles Working Group "Technology, Growth and Employment" framework :

- the review of the charging policy for scientific data transmission across borders ;
- the promotion of effective data communication standards in order to ensure compatibility.

The Working Groups recommend to the Versailles Working Group "Technology, Growth and Employment" that a study be conducted on this subject subsequent to the Bonn Summit and that a report on the steps that might be taken to improve conditions related to the above mentioned administrative impediments to effective cooperation be submitted to the subsequent Economic Summit.

Report to the Working Group
on Technology, Growth, and Employment
Bonn Economic Summit
May 1985

Area for Collaboration:	High Energy Physics
Lead Country:	United States of America
Participants:	Canada, France, Federal Republic of Germany, Italy, Japan, United Kingdom, European Communities

AIM

The aim of the Summit Working Group on High Energy Physics is to further develop international collaboration to foster progress in this field of scientific research.

ACTIVITIES

In regard to Article 22 of the "Technology, Growth, Employment" Working Group report to the London Summit, the High Energy Physics Working Group has found that, since its establishment, international collaboration has increased in the use of present accelerators and in the planning for future accelerators. Moreover, continuing collaboration in long-range accelerator and detector technology development will lay the groundwork for further international collaboration in construction and use of future accelerators in this area of fundamental research. The Working Group has identified a number of obstacles of an administrative nature that hamper effective collaboration.

OUTLOOK

This Working Group has provided a unique forum for discussion of this area of basic science. It is of the greatest importance to continue to review long-term plans for major facilities and related technological research activities on an intergovernmental basis. This should enable progress in this most fundamental science, rich in technical spin-offs, to continue in an orderly, cost-effective way within limited resources.

It it hoped that a Summit endorsement of an indepth review of administrative obstacles to effective international collaboration in science and technology will lead to coordinated action to eliminate them or to mitigate their negative impact.

APPENDIX A

Château de Versailles
4, 5 et 6 juin 1982

DECLARATION OF THE SEVEN HEADS OF STATE AND GOVERNMENT AND REPRESENTATIVES OF THE EUROPEAN COMMUNITIES

In the course of our meeting at Versailles we have deepened our mutual understanding of the gravity of the world economic situation, and we have agreed on a number of objectives for urgent action with a view to improving it.

We affirm that the improvement of the present situation, by a further reduction of inflation and by a return to steady growth and higher levels of employment, will strengthen our joint capacity to safeguard our security, to maintain confidence in the democratic values that we share, and to preserve the cultural heritage of our peoples in all their diversity. Full employment, price stability and sustained and balanced growth are ambitious objectives. They are attainable in the coming years only if we pursue policies which encourage productive investment and technological progress ; if, in addition to our own individual efforts, we are willing to join forces, if each country is sensitive to the effects of its policies on others and if we collaborate in promoting world development.

In this spirit, we have decided to implement the following lines of action :

- Growth and employment must be increased. This will be attained on a durable basis only if we are successful in our continuing fight against inflation. That will also help to bring down interest rates, which are now unacceptably high, and to bring about more stable exchange rates. In order to achieve this essential reduction of real interest rates, we will as a matter of urgency pursue prudent monetary policies and achieve greater control of budgetary deficits.It is essential to intensify our economic and monetary cooperation. In this regard, we will work towards a constructive and orderly evolution of the international monetary system by a closer cooperation among the authorities representing the currencies of North America, of Japan and of the European Community in pursuing medium-term economic and monetary objectives. In this respect, we have committed ourselves to the undertakings contained in the attached statement.

- The growth of world trade in all its facets is both a necessary element for the growth of each country and a consequence of that growth. We reaffirm our commitment to strengthening the open multilateral trading system as embodied in the GATT and to maintaining its effective operation. In order to promote stability and employment

through trade and growth, we will resist protectionist pressures and trade-distorting practices. We are resolved to complete the work of the Tokyo Round and to improve the capacity of the GATT to solve current and future trade problems. We will also work towards the further opening of our markets. We will cooperate with the developing countries to strengthen and improve the multilateral system, and to expand trading opportunities in particular with the newly industrialized countries. We shall participate fully in the forthcoming GATT Ministerial Conference in order to take concrete steps towards these ends. We shall work for early agreement on the renewal of the OECD export credit consensus.

-We agree to pursue a prudent and diversified economic approach to the U.S.S.R. and Eastern Europe, consistent with our political and security interests. This includes actions in three key areas. First, following international discussions in January, our representatives will work together to improve the international system for controlling exports of strategic goods to these countries and national arrangements for the enforcement of security controls. Second, we will exchange information in the OECD on all aspects of our economic, commercial and financial relations with the Soviet Union and Eastern Europe. Third, taking into account existing economic and financial considerations, we have agreed to handle cautiously financial relations with the U.S.S.R. and other Eastern European countries, in such a way as to ensure that they are conducted on a sound economic basis, including also the need for commercial prudence in limiting export credits. The development of economic and financial relations will be subject to periodic ex-post review.

- The progress we have already made does not diminish the need for continuing efforts to economise on energy, particularly through the price mechanism, and to promote alternative sources, including nuclear energy and coal, in a long-term perspective. These efforts will enable us further to reduce our vulnerability to interruptions in the supply of energy and instability of prices. Cooperation to develop new energy technologies, and to strengthen our capacity to deal with disruptions, can contribute to our common energy security. We shall also work to strengthen our cooperation with both oil-exporting and oil-importing developing countries.

- The growth of the developing countries and the deepening of a constructive relationship with them are vital for the political and economic well-being of the whole world. It is therefore important that a high level of financial flows and official assistance should be maintained and that their amount and their effectiveness should be

increased as far as possible, with responsibilities shared broadly among all countries capable of making a contribution. The launching of global negotiations is a major political objective approved by all participants in the Summit. The latest draft resolution circulated by the Group of the 77 is helpful, and the discussion at Versailles showed general acceptance of the view that it would serve as a basis for consultations with the countries concerned. We believe that there is now a good prospect for the early launching and success of the global negotiations , provided that the independence of the Specialised Agencies is guaranteed. At the same time, we are prepared to continue and develop practical cooperation with the developing countries through innovations within the World Bank, through our support of the work of the Regional Development Banks, through progress in countering instability of commodity export earnings, through the encouragement of private capital flows, including international arrangements to improve the conditions for private investment, and through a further concentration of official assistance on the poorer countries. This is why we see a need for special temporary arrangements to overcome funding problems for IDA VI, and for an early start to consideration of IDA VII. We will give special encouragement to programmes or arrangements designed to increase food and energy production in developing countries which have to import these essentials, and to programmes to address the implications of population growth.

In the field of balance of payments support, we look forward to progress at the September IMF Annual Meeting towards settling the increase in the size of the Fund appropriate to the coming Eighth Quota Review.

- Revitalization and growth of the world economy will depend not only on our own effort but also to a large extent upon cooperation among our countries and with other countries in the exploitation of scientific and technological development. We have to exploit the immense opportunities presented by the new technologies, particularly for creating new employment. We need to remove barriers to, and to promote, the development of and trade in new technologies both in the public sector and in the private sector. Our countries will need to train men and women in the new technologies and to create the economic, social and cultural conditions which allow these technologies to develop and flourish. We have considered the report presented to us on these issues by the President of the French Republic. In this context we have decided to set up promptly a working group of representatives of our governments and of the European Community to develop, in close consultation with the appropriate international institutions, especially the OECD, proposals to give help to attain these objectives.This group will be asked to submit its report to us by 31 December 1982. The conclusion of the report and the resulting action will be considered at the next economic Summit to be held in 1983 in the United States of America.

APPENDIX B

Excerpt from the Communique of the London Economic Summit June 9, 1984

"We, the heads of state or government of seven major industrialized countries and the President of the Commission of the European Communities, have gathered in London from 7 to 9 June 1984 at the invitation of the Right Honorable Margaret Thatcher, the Prime Minister of the United Kingdom, for the 10th annual economic summit.

[2]

"The primary purpose of these meetings is to enable heads of state or government to come together to discuss economic problems, prospects and opportunities for our countries and for the world. We have been able to achieve not only closer understanding of each other's positions and views but also a large measure of agreement on the basic objectives of our respective policies.

[13]

"We welcome the further report of the working group on technology, growth and employment created by the Versailles economic summit and the progress made in the 18 areas of cooperation and invite the group to pursue further work and to report to personal representatives in time for the next economic summit. We also welcome the invitation of the Italian Government to an international conference to be held in Italy in 1985 on the theme of technological innovation and the creation of new jobs."

APPENDIX C

Working Group
on Technology, Growth and Employment
established by the Heads of State and Government
at the Versailles Summit,
June 4, 5 and 6, 1982

TECHNOLOGY
GROWTH
EMPLOYMENT

January 1983

EXECUTIVE SUMMARY

"Revitalization and growth of the world economy will depend not only on our own effort but also to a large extent upon cooperation among our countries and with other countries in the exploitation of scientific and technological development. We have to exploit the immense opportunities presented by the new technologies, particularly for creating new employment. We need to remove barriers to, and to promote, the development of and trade in new technologies both in the public sector and in the private sector. Our countries will need to train men and women in the new technologies, and to create the economic, social and cultural conditions which allow these technologies to develop and flourish. We have considered the report presented to us on these issues by the President of the French Republic. In this context we have decided to set up promptly a working group of representatives of our governments and of the European Community to develop, in close consultation with the appropriate international institutions, especially the OECD, proposals to give help to attain these objectives. This group will be asked to submit its report to us by 31 December 1982. The conclusion of the report and the resulting action will be considered at the next economic Summit to be held in 1983 in the United States of America."

Declaration of the Seven Heads of State and Government and Representative of the European Communities.
Château of Versailles, June 4, 5 and 6, 1982.

Consistent with this instruction, and at the initiative of the President of the French Republic, a Working Group of Representatives of Seven Heads of State and Government and the Representatives of the European Communities was set up to consider the opportunities, problems, and challenges presented by technology, with special regard to economic growth and employment. The Working Group met for the first time on August 20th, 1982.

Operating on the basis of consensus, the Working Group has produced a report which is essentially policy-oriented in nature and is addressed to Heads of State and Government*. The report is selective: it concentrates on our own countries except where we state otherwise. It also concentrates on problems where science and technology offer potential solutions, but it does not pretend that science and technology provide a panacea.

(*) In this report the word "government" is also taken to include the European Communities.

The Group has completed its task, and has offered the following conclusions and recommendations:

•Major advances in science and technology have caused profound changes in our way of life for more than two centuries. These developments continue today at an even greater pace.

•Fundamental scientific research is one source of technological progress in industry and should be given special support by governments.

•Technological innovation can play an important role in the increase of the level of employment and the improvement of labour conditions. Special training programmes are necessary to promote flexibility, mobility and adaptability of labour.

•Our nations should make a better effort to prepare their citizens for living and participating in a society of an increasingly technical nature.

•The fate of our scientific and technological innovations is largely a function of the willingness of the public to accept them. More attention to the problem of public acceptance of new technologies is needed.

•Special attention should be paid to the rejuvenation of mature industries through the use of science and technology.

•Sustained technical progress is best promoted through a balanced distribution of productivity gains between further investment and increased consumption.

•An open and competitive trading system between autonomous but collaborating partners should be strengthened by harmonising and making more compatible our regulatory and testing systems. Care must be taken by governments to control the transfer of sensitive technologies of military significance to our countries.

•Science and technology can be applied to many of the problems faced by the developing world. As developing countries create infrastructures in science and technology, our own countries should recognise the constructive role which they are able to play, mindful that it is the responsability of the developing countries, as sovereign nations, to establish their own national policies and priorities.

•The market introduction of new technologies is primarily the task of the industrial and commercial sectors. A competitive atmosphere is essential for this type of innovation, since it creates a continuous evolution of technological progress and, thereby, long-term economic growth. Governments should support fundamental science and long-term, high-risk research and development activities.

•Governments need to generate and support the framework conditions for workable competition and provide incentives for innovation through the encouragement of invention and investment in innovation.

•National policies in areas such as regulatory standards, tax, patent and trade all influence our ability to innovate and to reap the full benefits of innovation. The Group recognises and endorses the efforts of the OECD to resolve some of the problems faced in this area. We reaffirm our commitment to removing barriers to an open multilateral trading system, to strengthening the rules in this connection, and to promoting the development of trade in new technologies,

particularly for creating new employment, and therefore, shall seek to intensify our contacts bilaterally and in all relevant fora. In this regard, the Group takes note that discussions of these items will be pursued in the GATT Council.

•*Science and technology are a source of national and international strength and can provide immense opportunities for revitalisation and growth of the world economy. They should therefore be given due consideration in all policy decisions for national development and international cooperation.*

•*International cooperation in science and technology has demonstrated its value. Governements should continue to support cooperation, including the international scientific organisations.*

•*With current economic difficulties and with national budgets subject to greater constraint, it makes even more sense to cooperate internationally, in particular, in long-term, high-risk research and development projects.*

•*Already existing international cooperation in science and technology should be continued and, where appropriate, enlarged. An effective exchange of ideas and researchers must be strongly encouraged.*

•*The cooperation begun under the auspices of this Working Group forms a solid base for future action and should continue in the relevant fora.*

•*Finally, we recommend to our Heads of State and Government that, bearing in mind the role that science and technology can play in improving economic growth and employment, and in stimulating culture and education, they take science and technology into account in their policy decisions and continue to include the subject on their agenda at future Summit meetings.*

The Working Group has also reviewied a number of scientific and technological issues with a view towards determining where additional international collaboration could best contribute to increased understanding and improved social and economic conditions, not only for our own people, but for all the world.

In this process, we noted that a wide range of cooperation is already under way in important and wide spread areas such as:
—conquest of space;
—renewable sources of energy;
—research on safety of light water reactors;
—deep ocean drilling.

We appreciate this effort and encourage its development using existing multilateral and bilateral frameworks.

We also propose the following collaborative projects which are either new or incorporate significant re-focussing in order to achieve:

I. Stimulation of the conditions for growth by better management of energy resources by:
—photovoltaic solar energy;
—controlled thermonuclear fusion;
—photosynthesis;
—fast breeder reactors.

II. Better management of food ressources by:
- —food technology;
- —aquaculture.

III. Improvement of living conditions, employment, and protection of the environment, through:
- —remote sensing from space;
- —high speed trains;
- —housing and urban planning for developing countries;
- —advanced robotics;
- —impact of new technologies on mature industries;
- —biotechnology;
- —advanced materials and standards;
- —new technologies applied to education, vocational training and culture;
- —public acceptance of new technologies.

IV. General increases of scientific knowledge, particularly in:
- —biological sciences;
- —high energy physics;
- —solar system exploration.

APPENDIX D

Working Group on
Technology, Growth, and Employment
January 1983

Charges to the United States of America

GENERAL INCREASES
IN BASIC SCIENTIFIC KNOWLEDGE,
PARTICULARLY IN

HIGH ENERGY PHYSICS
(United States of America)

High energy physics is an important basic research activity which addresses the most fundamental questions of the nature of matter. This field has had many spinoffs of direct application to other areas of science and technology. Experimental research in high energy physics requires the use of a limited number of expensive particle accelerators and colliding beam facilities which have been constructed with government support.

A few large and costly machines are being constructed in different regions of the world to meet future needs. It is anticipated that scientists from each region will continue to be able to participate in experiments at these large facilities on the basis of the scientific merit of their proposals. Such international collaboration avoids unnecessary duplication of costly facilities.

In the mid-1990's further progress will probably require a new generation of very high energy accelerators costing huge sums of money. Such facilities are likely to exceed the financial capabilities of any single nation or region. An international cooperative program should therefore be considered. The decade of effort required for definition, design, and construction indicates that these discussions should begin in the near future.

APPENDIX E

Report to the Working Group
on Technology, Growth, and Employment
London Economic Summit
June 1984

Area for Collaboration: High Energy Physics

Lead Country: United States of America

Participants: Canada, France, Federal Republic of Germany, Italy, Japan, United Kingdom, European Communities

AIM

The aim of the Summit Working Group in high energy physics is to further develop international collaboration to foster progress in this field of scientific research.

ACTIVITIES

The Working Group has surveyed the existing national programs and their associated international activities and commitments for major new facilities that have been made or proposed by Summit member nations. The general consensus was that worldwide collaboration works well. Major research projects in high energy physics are seldom done exclusively by groups or individuals from any one nation. The existing arrangements for collaboration should be maintained as the essential basis for future international cooperation.

At the present time, a number of major new accelerator projects are being built in Germany, Japan, the United States, and at CERN. Looking further to the future, there are proposals both in Europe and the United States for new colliding beam accelerators. Because these commitments and proposals extend into the 1990's, the Working Group concluded that it was not possible to plan for the long-term at this time. However, substantial research and development is needed in the necessary accelerator and detector technology for projects beyond those under construction and proposed. It was decided to explore the possibility that this research and development could be conducted in collaboration in the spirit of the Declaration of Versailles. A subpanel of technical experts from each Summit member was established to recommend specific technical areas for near-term joint collaborative research. The subpanel recommended the areas of superconducting magnets, cryogenics, rf cavities, very high-energy electron linacs, theory and simulation, and new technologies of acceleration.

OUTLOOK

A July meeting of the Working Group has been scheduled to review the proceedings of the London Summit and also to review the recommendations of the technical subpanel. A proposal will be introduced for the Working Group to organize other technical subpanels of similar composition and work with them to develop a plan identifying the major facilities that will be required to continue to make effective progress in this field, regardless of location. This plan could be completed for the next Summit meeting.

APPENDIX F

IMPROVING INTERNATIONAL COLLABORATION IN HIGH ENERGY PHYSICS

Report of the Technical Sub-panel of the Summit Working Group on High Energy Physics

February 1984

I. INTRODUCTION AND SUMMARY

The Technical Sub-Panel of the Summit Working Group on International Collaboration in High Energy Physics met at the Stanford Linear Acclerator Center January 30, 31 and February 1. Our charge was to make recommendations on specific areas in high energy physics that might be appropriate for increased international collaboration and to indicate how non-summit nations might become more involved in this type of work. The members of the technical working group were:

Prof. Burton Richter, Chairman, Stanford Linear Accelerator Center (U.S.A.)

Dr. Ewart Blackmore, TRIUMF (Canada)

Dr. Giorgio Brianti, CERN (EEC)

Prof. Kunitaka Kondo, University of Tsukuba (Japan)

Dr. Joao Meyer, CEN-Saclay (France)

Dr. J. H. Mulvey, Oxford (England)

Prof. Sergio Tazzari, INFN Frascati (Italy)

Dr. G. A. Voss, DESY (Germany)

We first discussed the several kinds of R&D activity and identified three modes which seem to span all of the work that now takes place, and which appear sufficiently flexible to encompass just about anything one would want to do. They are as follows:

Parallel Parallel R&D is what we mostly do now. In this mode independent efforts are carried out in many places. No joint funding and no formal coordination of work takes place. All of the institutions build on the efforts of others through the usual methods of information exchange — meetings, papers and technical visits. Examples of this mode are superconducting accelerator magnet development and accelerator theory.

Collaborative Collaborative R&D is that mode in which two or more groups or institutions decide to pool their resources for doing R&D activity on a particular topic. Funds and people may flow across national boundaries to advance a common effort.

Coordinated Coordinated R&D is that mode in which several participants each concentrate on different approaches to the same general goal. We do not know of examples of formal agreements to proceed in this manner, but it is often done informally.

Within this framework we discussed possibilities for increased international efforts in accelerator R&D, detector R&D and experimental exploitation of accelerators, communication, expanding the involvement of other institutes and countries, and accelerator construction. A summary of our conclusions and recommendations follows.

In all of our discussions we found one particular topic coming up again and again — that topic is communications. Improved communications can increase the possibility of international collaboration in all areas of high energy physics and indeed in all areas of science. This is one topic that is particularly well addressed to the Summit for it is national telecommunications policies which create barriers to better communication. Our recommendations are as follows (see Section IV for details).

> **Rec. 1** Remove the telecommunications barriers to direct high-speed institution-to-institution communications.
>
> **Rec. 2** Investigate the possibility of low-cost high-bandwidth satellite channels for scientific communications.
>
> **Rec. 3** Set up a special technical working group to develop protocols and standards for computer-to-computer communications in high energy physics.

Our group next turned to a discussion of possible areas for improved collaboration in accelerator R&D. We discussed superconducting magnets, cryogenics, very high-energy electron linacs, new techniques of acceleration, and theory and simulations. We have nine recommendations in this area.

> **Rec. 4** The development of niobium-tin conductors for high magnetic fields would profit from coordinated R&D on different kinds of processes for creating high-current-density, small-diameter filaments. Collaborative R&D might follow.
>
> **Rec. 5** Collaborative R&D on a few selected technologies for improvements to superconducting magnets at all magnetic field ranges would be worthwhile after a further period of parallel and coordinated work.
>
> **Rec. 6** At the present stage of development, exchanges of experts are extremely important, and such exchanges should be encouraged.
>
> **Rec. 7** A joint working group on the economics of superfluid helium cryogenic systems should be set up, because one of the barriers to going to higher magnetic fields with our standard conductor is the fear of greatly increased cryogenic system costs.

Rec. 8 Coordinated and collaborative efforts on superconducting rf systems should be encouraged; such systems may prove to be very useful in large proton accelerators and storage rings as well as in the electron storage rings for which they are now being developed.

Rec. 9 There is a broad range of technologies which are important for the development of very-high-energy electron linear accelerators and colliders where increased collaborative and coordinated R&D could be very beneficial.

Rec. 10 In the area of new acceleration techniques, parallel and coordinated efforts are most appropriate at this stage of development. Collaborative efforts would become appropriate at a later stage.

Rec. 11 R&D on some of the new acceleration techniques would benefit if access, by internation teams, to special facilities such as large lasers and induction linacs were easier.

Rec. 12 Coordinated efforts in accelerator theory and computer simulation would be extremely beneficial, and collaboration on tests of theoretical models in existing accelerators will be required to validate this theoretical work.

International collaboration in detector R&D and experimentation is already the normal mode of operation in high energy physics. The international collaborations work very well but would benefit greatly from the improvements in communication recommended earlier. We have two further recommendations in this area.

Rec. 13 Encourage the maintenance of home-based programs in order to preserve the basis for the existing collaborations in detector R&D and usage.

Rec. 14 In certain countries there are customs barriers to importing equipment built outside of that country which is essential for a collaborative experiment. These customs barriers should be removed.

Our discussions next turned to the problem of broadening the base of support for high energy physics and involving non-summit and less developed countries. Accelerator physics has many applications outside of high energy physics, such as synchrotron radiation sources, medical accelerators, etc. Accelerator physicists are in short supply, and work in high energy physics as well as in these other areas is already impeded by a shortage of skilled personnel. In addition, much of advanced technology is in routine use in high energy physics accelerators and experiments. Exposure of scientific and techni-

cal personnel from less developed countries could aid in transferring this technology to those countries whether or not they chose to be involved in high energy physics. We have three recommendations in this area.

Rec. 15 Encourage fellowships at the major centers for scientists, engineers and technicians from non-summit and less developed countries to aid in the development of high energy physics programs and to facilitate the transfer of technology used in high energy physics to others.

Rec. 16 Encourage universities and technical institutes to develop programs in accelerator physics; many problems in this field involve inter-disciplinary work that is well-suited to a university setting, the supply of accelerator physicists is small, and the application range of accelerator technology is broad.

Rec. 17 Encourage regional and international schools in accelerator physics to attract more high energy physicists and physicists with other backgrounds into the accelerator field.

Finally we discussed possible collaborations on accelerator construction. Such collaborations will have additional financial and scientific costs because of increased complexity and infrastructure, as well as benefits in reduced national contributions to a particular project. The costs are significant, and thus it seems appropriate to create international collaborations for accelerator construction only in those cases where one region or nation cannot bring to bear the necessary resources to carry out an entire project. This is clearly a complex issue and will require a great deal of discussion among the summit countries before any collaborative projects are begun. We have no specific recommendations in this area.

II. ACCELERATOR R&D

A. Superconducting Magnets

After two decades of development of superconducting magnets, a number of very important achievements have been made in the last few years. The most significant of these is the TEVATRON at Fermilab (1 TeV hadron accelerator/collider). Very successful developmental and prototype magnets have been built for CBA, for HERA (0.8 TeV proton ring at DESY) and for UNK (3 TeV proton ring at Serpukhov). In Japan, models of high field magnets are being developed for the proton ring of TRISTAN. All this work demonstrates that large superconducting magnet systems can be built and operated.

In parallel with this technological development, the recent experience with the CERN SPS Collider has shown that energetic collisions between hadron constituents can be quite readily identified among the lower energy debris of the spectator particles, and this has also enhanced the interest in large hadron colliders (center-of-mass energy of 10 to 40 TeV) both in the USA and in Europe.

For such large colliders it is imperative to use superconducting magnets in order to keep their cost, their power consumption and/or their size within reasonable limits. Substantial R&D work is required in order to obtain still better performance, to lower the total cost, and to increase the reliability. This R&D work can conveniently be subdivided into two categories:

1. Development of new conductors and related magnet construction techniques suitable for fields $\geq 8T$ (high fields);
2. Improvement of conductors and techniques for fields in the range $2T$ to $6T$ (low to medium fields).

The most substantial basic development is required for the first category, while cost considerations are important for both categories in order to allow the final choice to be made on sound economic grounds.

HIGH FIELD CONDUCTORS AND MAGNETS ($\geq 8T$)

Two lines of development are open here: Nb_3Sn conductor used at $\sim$ 4.5°K, and $NbTi$ used at $\sim$ 2°K. In principle the most promising material is Nb_3Sn because of its higher critical field and higher temperature (more relaxed cryogenic system). Its drawback is brittleness and fragility, which requires either final reaction of the composite

to obtain the superconducting state after winding, or else magnet coils wound with relatively large radii using pre-reacted material. Nb_3Sn has been produced for many years, but the specific requirements for this application of small-bore magnets operating over a wide field range (maximum field about twenty times the injection field) are the following:

- high current density,
- superconducting filaments of small diameter.

Winding and insulation techniques compatible with a heat treatment of $\sim$ 700°C for a few hours, or methods of avoiding too small bending radii in winding of pre-reacted material, must also be developed.

The alternative line of development toward high fields is to use $NbTi$ conductors at lower temperature ($\sim$ 2°K). The advantage is that the material can be wound in the reacted state by means of well-established techniques, but the disadvantages fall on the cryogenic system — more complicated cryostats and larger power consumption. The maximum field is also more limited. This line is a convenient reserve should the development of Nb_3Sn encounter serious difficulties or lead to excessive costs.

Low- and medium-field magnets ($2T$ to $6T$)

Projects based on fields in the upper part of this range ($4.5T$ to $6T$) are a natural continuation of present work. The R&D required should be directed toward low cost and the development of industrial manufacturing techniques. The conductor development would be essentially the same as that required for the high-field case with $NbTi$ at 2°K.

Still lower fields, between $2T$ and $3T$, are also being considered. In this case the field distribution is shaped by iron boundaries, and the role of superconductor is to minimize the power consumption. These magnets are called superferric. The development needed here is directed toward simple, inexpensive design and cost-effective manufacturing techniques in order to counterbalance the increase in cost attributable to the longer tunnel and more spread-out infrastructure that would be required.

International collaboration

International collaboration in these development programs would be very beneficial. Such work should be aimed at enhancing technology transfer to the industries

of the collaborating regions. Specific elements in of such a collaboration might be the following:

- Common definition of possible new superconductors in order to minimize industrial investment for development and to enlarge potential markets.
- Joint selection of a small number of potentially interesting techniques and conceptual magnet designs to be tested by means of models.
- Eventually, coordinated fabrication and evaluation of full scale prototypes.

To assess the possibility of achieving these goals, the exchange of people between interested laboratories should be encouraged and supported as a first step.

OTHER APPLICATIONS

It should be emphasized that all of these developments could be beneficial to a number of applications in other fields, such as fusion, electrical power transmission, cryogenerators, energy storage and recovery, magnetic separation of minerals, nuclear magnetic resonance for medical and other applications, transportation, etc.

B. Distributed Cryogenic Systems

The large superconducting magnet systems described above require very substantial cryogenic systems for the production, transfer and recovery of *He*. Simple cryostats, a reliable and efficient liquifier plant, and low-loss transfer lines are very important elements of a satisfactory design, which must be tailored to each specific project. One point that deserves a careful assessment by experts is the possibility of using superfluid *He* at $\sim 2°K$ for such applications. An evaluation of the additional costs with respect to normal 4.5°K systems, because of their increased cryostat complexity and power consumption, is necessary to determine their interest. Such an evaluation should be conducted on an international basis.

C. Superconducting Radiofrequency Cavities

During the last few years superconducting radiofrequency (rf) accelerating structures have matured to the point where their use in large circular accelerators seems feasible and realistic. Multicell niobium structures have reached average accelerating gradients of more than 4 MV/m at negligible rf-power loss. Even considering the fact that these small remaining losses occur at the temperature of liquid helium and require powerful refrigerators, the overall power economy of superconducting resonators is one to two

orders of magnitude better than that of conventional copper structures. The fact that the accelerating gradients are more than a factor of four higher than those in copper structures (in cw operation) makes these superconducting resonators very well suited to applications in which large rf accelerating voltages are required in a continuous operation, i.e., in electron and proton storage rings.

These new structures have been studied at a number of different laboratories in the U.S., Germany, France, Japan, Italy, and at the CERN laboratory. Successful and reliable operation at high accelerating gradients has been demonstrated at the electron-positron storage rings CESR (Cornell University) and PETRA (DESY, Hamburg). To make this new technology more economical and attractive for routine operational use, vigorous development programs are now under way at several laboratories. These efforts include the development of copper structures with a superconductive niobium coating, simplifications in the cryogenic technology, special cavity shapes to suppress excitation of higher resonances, and simple techniques for industrial production.

In view of the importance of this new technology and the magnitude of the effort necessary to develop efficient production techniques, this field is very suitable for an international coordinated and collaborative effort.

D. Very High Energy Electron Machines

Electron-positron colliding-beam experiments have been extremely productive in studies of the structure of matter and of the forces that act between the basic constituents. The present technique, the colliding-beam storage ring, has been in use for about 25 years; during that time, the radii of these machines have increased 5000-fold while the collision energies have increased 100-fold. With a mature technique like the colliding-beam storage ring, the known scaling laws can be used to predict the cost of a new facility to an accuracy of 10% to 20% without going through a detailed design. This has been done for the LEP facility now under construction at CERN.

Applying these known scaling laws to determine the size and cost of the next logical step, a machine capable of producing particles with masses in the TeV range results in a cost estimate of the order of $100 billion and a circumference of many thousands of kilometers. Even if there were no technical barriers to the construction of such a machine, there is certainly a fiscal barrier.

For the past several years work has been going on in both the U.S. and USSR on an alternative to the Storage Ring — the Linear Collider. R&D work has indicated

the feasibility of this new idea, and the first machine using this technique, the Stanford Linear Collider (SLC), is now under construction in the U.S. This "proof of principle" machine is based on improvements to the existing Stanford 30 GeV linear accelerator to allow the collider to reach 100 GeV in the center-of-mass, and it is scheduled for completion near the end of 1986. Successful operation of the SLC will give confidence that the technique can be extended to much higher energies.

Parametric studies of large linear colliders indicate that significant reduction in the cost of a big machine can be made by improvements in accelerator structures, power sources and energy efficiency. Potential topics for an R&D program include basic work on the ultimate breakdown strength of copper (which determines the maximum accelerating field and hence the minimum length of accelerator needed for a given energy); very high power, high efficiency rf sources (which affects the number of power sources required, the practical maximum accelerating gradient, and the energy efficiency of the system); optimized accelerating structures; alternatives to conventional linacs for acceleration (see Section II.E); energy-recovery techniques; and theoretical work on the beam-beam interaction, on beam-acceleration structure interaction, and on focusing techniques for producing sub-micron focal spots at the collision point.

At present, interest among the summit countries is highest in France, Germany, Japan, and the United States. Bilateral or multilateral programs — formal or informal — should be encouraged in order to increase the pace of the work and to avoid unnecessary duplication of effort.

E. New Techniques of Particle Acceleration

Particle acceleration techniques have been developed over 50 years with striking efficiency: the maximum energy of accelerators has increased by a factor of ~ 35 every ten years, and the cost per unit energy has decreased by a factor of ~ 30 over the last 25 years. The size and cost of the required facilities has nonetheless continued to grow. While the next generation of machines is already being studied by extrapolating the known techniques to even higher energies, it has become clear that on a longer time scale new ideas will be needed on how to obtain even higher energies without excessively increasing the size of the facilities. The history of accelerator work indicates that major developments of the kind considered here might well need 10-20 years to evolve from the stage of conception to the point where they are actually used in a new machine.

A number of novel ideas have been recently developed that are aimed at producing accelerating and/or focusing fields about one order of magnitude higher than those at present achievable. Some of these new ideas are listed in Table I.

Table I

Some proposed novel acceleration techniques and related topics.

Type	Aim	Work in Progress at	
Wake field	>0.1 GeV/m	DESY	experimental
		Japan Virginia Stanford	theoretical
Inverse free electron laser	$\gtrsim 0.2$ GeV/m	BNL NRL	theoretical
Laser beat wave	~ 10 GeV/m	NRL Chalk River Los Alamos UCLA	
		Stanford CERN Rutherford	theoretical
Two-beam	>0.1 GeV/m	LBL	experimental
Near-field (grating LINAC,...)	~ 10 GeV/m	BNL Cornell	theoretical
Free electron laser	tunable high power sources	ORSAY Stanford Frascati BNL Japan	experimental
		UK (Glasgow/Daresbury)	
Very high power tubes (Gyrotron,...)	~ 1 GW	Maryland Stanford	

There are several features common to all these schemes

1. They are all in the very early stages of development. Some are at the level of theory, while others are at the level where proof-of-principle experiments have just been started. Some are well suited to study by university or small laboratory-based teams.
2. The work generally needs a higher level of interdisciplinary collaboration than more conventional accelerator physics work. This is again more likely to be found at the university level.
3. These schemes link the development of high-energy accelerators to techniques that are being developed in many different institutions for other purposes, such as very intense low-energy electron beams, free electron lasers, etc.

In order to be reasonably certain that one or more of these new schemes will eventually prove to be of practical significance, as many as possible will have to be developed to a stage where a realistic assessment can be made. The advantage of widespread international collaboration — in order to cover the maximum number of approaches within the available resources — is quite evident here.

The following recommendations are made:

1. Accelerator R&D work should be encouraged at both the national and regional level, and in both small and large institutions, because it is ultimately from a widespread base of such work in universities and in laboratories that new ideas will emerge.
2. Unique facilities not usually available in small centers — such as very high current induction linacs (mostly in the U.S.), high power laser systems (both in the U.S. and in Europe), and beam time at existing accelerators — should be made available to the research teams engaged in this type of research.
3. Exchanges of people, both in accelerator physics and in related areas such as plasma physics, between groups engaged in research should be made easy, in order to facilitate the effort.
4. In the present stage, where more ideas are sought and where useful effort can be made on a small scale, maximum diversity of effort along with maximum exchange of information (and tools) should be encouraged, as recommended above. A further step-up in international cooperation, leading to collaborative and/or

coordinated work, will be required as soon as larger scale pilot facilities start to be planned.

F. Accelerator Theory and Computer Simulation

Optimizing the design of a new high energy accelerator requires a thorough understanding of machine physics phenomena and of the limitations these phenomena might impose on the performance. In the past, unexpected phenomena have sometimes limited the performance of a new machine, leading to the need for corrective measures that were sometimes rather costly. As machines get larger and costlier, it is even more important to try to avoid surprises of this kind.

Our analytical understanding of the phenomena that govern single-particle dynamics in large accelerators, and also of high-current effects and the behaviour of particle bunches with high charge densities, has vastly improved during the last 25 years. However, many of the effects that can lead to single-particle resonances, to collective beam instabilities, or to beam-beam-interaction limitations (in storage rings), are too complex to be treated in an analytical way.

Modern computers make it possible to calculate accurately the fields generated by the high-density particle bunches in an accelerator structure, as well as the effects of these fields acting back on the individual particles. By tracking the particles over many turns, and by simultaneously calculating the fields they produce and their effects on the particle trajectories, one can simulate the beam behavior. Such a computer simulation can then be compared with the effects observed in actual machines. In this way the validity of a particular computer simulation approach can be established, and predictions about future machines can be made with confidence. Work in this field has been going on in most of the major accelerator laboratories around the world. Methods and results have been discussed and compared at international meetings and at special summer schools.

Simulations that simultaneously take all relevant effects into account and that also follow the particles for many turns (as may be necessary for proton storage rings) can be very expensive in terms of computer time. Because of this, and also because some large computers are considerably more suitable for this work than others, it is very desirable to coordinate these activities and to have as much collaboration as possible. Experiments on existing accelerators, with the aim of testing the computer predictions, should also be part of such international collaborative effort. Another important part

of such a program would be tests of new techniques in the accelerator field that can be performed on existing machines (e.g., stochastic cooling of bunched beams).

The recommendation of the Sub-panel is to encourage the development of a co-ordinated program through a series of specialized international workshops. The most important aspects of such a program would be the following:

1. Access to the most suitable computer systems for large-scale tracking and simulation programs.
2. Machine time at existing accelerators to test and verify the predictions made by analytical theories and by computer simulation programs.
3. Machine time at existing accelerators to test new techniques that will be needed to upgrade existing machines and to incorporate in future machines.

III. DETECTORS FOR HIGH ENERGY PHYSICS

A. Introduction

Particle-physics research during the 1980's and 1990's is expected to be led by experiments at the highest energy e^+e^-, $\bar{p}p$, pp and ep colliders. Because of their immense size and cost, there are only a few such accelerator facilities throughout the world. However, the use of these facilities is an international endeavor. In fact, almost every major experiment at colliders today has an international or inter-regional flavor. The large general-purpose detectors used at these facilities have reached a level of size, complexity and sophistication that rivals those of the large accelerators at which they are used. The development of these detectors offers perhaps the best example of how well international and inter-regional collaborations work at the present time, and also demonstrates the important benefits that the participating countries derive from these collaborations.

Existing collaborations have shown that it is quite possible for small university groups as well as the larger national laboratories to make a significant contribution to these international detectors. The collaborations are usually informal and are driven by the participants' common interest in pursuing a particular physics goal.

There is a clear benefit for nations that do not have their own large accelerator facility to use this method to provide their scientists with an opportunity to take part in forefront physics, and also to derive benefits in terms of technological spin-offs from the exchange of ideas. This can be done with a relatively small investment compared with the cost of the total facility. There are also clear benefits for those nations that do have high energy accelerator facilities to participate in international collaborations at an appropriate level.

This section on detectors will briefly describe three typical collaborations: one that has recently made significant discoveries, one that is presently in the construction phase and one that is presently in the design phase. This will be followed by a description of some of the detection techniques and the areas of detector development that appear most promising. Not all of the significant particle physics experiments are carried out at the highest energy accelerators. There are non-accelerator experiments such as proton decay searches, and also experiments that are carried out with kaon, meson and neutrino beams produced by high current accelerators operating at lower energies. Some of this work will also be described. Finally, there are several recommendations

the Sub-panel wishes to make that could improve the already excellent collaborative efforts in developing experimental equipment for high energy physics.

B. Examples of Present Collaborations

UA 1

The discovery of the W and Z bosons at CERN in 1983 ranks as one of the greatest achievements in science, in accelerator technology and in detector design. The *UA* 1 collaboration and its sister experiment *UA* 2 set out to study proton-antiproton collisions at 540 GeV with large general purpose detector systems. To illustrate the size of the collaboration, the *UA* 1 team involves some 130 physicists from 14 research centers in 7 different countries. The *UA* 1 detector represents the accumulation of many years of knowledge in the design, construction and operation of particle physics experiments. Details of this 2000-ton detector are readily available in the literature. It does not make use of any new detection techniques but instead relies on careful exploitation of existing methods, on precise measurement of particle energies, and on skillful triggering and subsequent data analysis. Responsibility for the various components of the detector was delegated to the different research centers in the collaboration, and in most cases the individual components were constructed at the home institutions. The success of this effort demonstrates the effectiveness of this particular international collaboration and more generally the fact that the logistics and sociology of the organization of large groups working across national boundaries are tractable problems.

CDF

The Collider Detector Facility (CDF) is a large detector now being built for use with the Tevatron I proton-antiproton collider at Fermilab. The collaboration consists of groups from 15 institutions in the United States, Japan and Italy. Responsibility for the design and construction is subdivided among the university and institutional groups working under the coordination of Fermilab. The large superconducting magnet for this detector is being constructed by Japanese industry. The Japanese participation in this collaboration is funded by the U.S.-Japan Cooperative Program on High Energy Physics.

OPAL

OPAL is one of the four large international collaborations that were chosen in 1982 to construct detectors for LEP, the large electron-positron storage ring presently being built at CERN. The institutions involved are from the U.K., Germany, Italy, Canada,

France, Israel, Japan, the U.S. and Switzerland. In the case of Canada, for example, which has a relatively low funding level for high energy physics, OPAL represents a commitment of a significant portion of the high-energy physics funds within the country on a single important project. Japan, which is constructing TRISTAN, a similar e^+e^- collider at lower center-of-mass energy, is also making a significant contribution to the OPAL experiment. The mode of collaboration is such that each group contributes to the cost of the magnet, and each group then has responsibility for designing and constructing one of the components or subsystems of the detector.

C. Detector Research and Development

Detectors for high energy physics can be divided into two broad classifications — tracking detectors which measure the trajectories of charged particles usually in a magnetic field, and calorimeters which measure the energy distribution of the particles. Detector techniques have evolved primarily from a number of independent efforts in various laboratories, each effort reinforced by exchange of ideas and information with the other laboratories. Small university institutions can make significant contributions to detector techniques, although usually the actual exploitation of these techniques in large detectors requires the resources that are available in the larger laboratories.

As examples of recent developments in detector technology, the Time Projection Chamber (TPC) and the Ring Imaging Cherenkov (RICH) counter will be described. The time projection chamber is the name given to a class of large volume drift chambers. The pioneering work was done at Berkeley for a detector to be used with the PEP machine at SLAC. The idea was exploited by a group at TRIUMF, where a TPC was used in a rare decay experiment. Two exotic variations of this detector have been developed, one using high pressure hydrogen gas at Fermilab, and a second using liquid argon at the University of California, Irvine. The ALEPH and DELPHI detectors at LEP, the CDF detector already described, and the TOPAZ detector at TRISTAN plan to incorporate TPC's. There has been no formal coordination of this development effort; it is rather an example of a parallel R&D program.

The ring imaging Cherenkov detector has recently emerged as a serious technique in the measurement of particle velocities and hence as a method for particle identification. The original idea for this detector came from a university in France. The properties of a large aperture RICH detector were measured at Fermilab, the result of a collaboration between CERN, Saclay, Japan and Fermilab. This effort is an example of a coordinated

approach to detector development.

Calorimetry is one of the basic components of present and future detectors for collider experiments. The search for new materials of improved performance is an important step in the development of these detectors. Large scale calorimeters could exploit substantial amounts of materials such as uranium. International cooperation may be necessary for this to happen. A critical feature of calorimeters for the next generation of colliders is fine segmentation both in the longitudinal and lateral directions. For the collection of data from highly segmented calorimeters, the use of FASTBUS or a similar readout system is required. Special electronics is also required in the trigger systems for large detectors. To select interesting events from a huge uninteresting background, triggering decisions will have to be made on-line with features such as rapid track reconstruction and pattern-recognition units that are provided with special front-end processors. The development of these devices will be more effective if the combination of parallel and collaborative efforts that is presently taking place is strengthened.

D. Data Acquisition and Exploitation of Large High Speed Computers

The benefits of cooperation in data analysis and software development, and the advantages of improvements in computer networking, are described in Section IV and will not be repeated here.

E. New Ideas in Detector R&D

Detectors for the new colliders face many new challenges. For example, experiments at the Stanford Linear Collider (SLC) with its micron-size beams would benefit from improved spatial resolution if the existing 50-100 micron resolution of drift chambers could be improved to a level of about 5 microns. Micro-vertex detectors that can identify the secondary vertex when bottom or charm quarks are produced are presently being developed. An area that is ripe for collaborative work is the use of charge manipulation structures of silicon or gallium-arsenide for particle detection. Silicon strip detectors are presently being used successfully in particle physics experiments and have demonstrated 5 micron spatial resolution. Two-dimensional Charge-Coupled Devices (CCD) are being developed for television cameras and other optical imaging applications by industry; there is a clear benefit here in a collaborative approach both between laboratories and between laboratories and the micro-electronic industry.

F. Non-Accelerator Based Detectors

Stimulated by theoretical predictions based on grand unified theories and gauge theories, there are several active projects underway to search for proton decay and magnetic monopoles, and to study cosmic-ray neutrinos. Examples are experiments at Utah in the United States, at Mont Blanc, Gran Sasso and Frejus in Europe, at Kolar in India, and at Kamioka in Japan. Some of these are already international collaborations. It is likely that the size and complexity of the next generation of such detectors will require international collaboration.

G. Recommendations

From the previous description of the state of present-day high-energy physics detectors, it is evident that very successful international collaborations have taken place and will continue to take place. Nevertheless there are several recommendations which, if implemented, would benefit this ongoing effort:

1. Detector systems for the next generation of machines will be larger and more complex, and will probably involve more institutions than at present. It is therefore necessary that improved communication networks be provided between laboratories to permit efficient coordination of the development and construction of the detectors, and subsequent analysis of the data.

2. A problem experienced by many groups is the difficulty of satisfying the customs regulations of the host country when large components of detectors are brought into the country. The reason is that this equipment has to stay for the duration of the experiment which may exceed five years. Further difficulties arise when subassemblies have to pass through several countries in the process of being fabricated into a complete detector. Some flexibility in the application of customs regulations for high energy physics apparatus would be an appropriate step toward improving international collaboration.

3. The importance of international collaboration in HEP experiments should be recognized by all countries, in particular those that do not have the highest energy facilities. To derive the maximum benefit from these collaborations in terms of technological transfer, training of graduate students and cultural benefit, there must be a strong home-base program. Detector R&D has been shown to be an activity well suited to individual home-base institutions. Adequate funding levels for both the home-base program and for international collaboration are necessary.

IV. COMMUNICATION AND STANDARDIZATION

Any discussion of how to improve international collaboration in high-energy physics quickly leads to the recognition that access to the most advanced communications technology is of central importance. It has a double impact: the direct benefits that accrue from efficient and rapid exchange of information; and, as a consequence, a greater readiness of the community to adopt 'standard' solutions to a wide range of problems, which in turn makes for greater ease and efficiency in collaboration.

A. Communication

In the design and construction of detectors, and in the performance of experiments, high-energy physicists already face the formidable management problems of research carried out in a truly international mode in a "world laboratory" — albeit one with accelerator facilities at several sites. At all stages, from preparation of the proposal through to analysis of the data, the one factor that can make a significant and much needed improvement in the effectiveness and efficiency of collaboration is an improvement in communication. Collaborators who share responsibility for the various components of a detector assembly could keep in close touch with the details of progress, and design and construction problems could be resolved as they arise. During data-taking at the accelerator laboratory, physicists and engineers at the home institutions could be consulted about problems or about modifications of the apparatus. In the analysis phase, all participants could access the data of the experiment from their own desks and take part in discussion of the results. Time spent in travel could be reduced, and university physicists would substantially increase the effectiveness of their contribution while fully maintaining their teaching commitments.

Although close collaboration of the kind found in the area of detector development and use is not yet typical of accelerator development and construction, similar facilities for communication are essential if this pattern is to change in the direction of increased collaboration. The modes of communication required include:

1. Transmission of text (electronic mail) including long documents.
2. Transmission of program files, essential for software standardization, with updating.
3. Remote access to special computer facilities.
4. Transmission of technical data in graphical form.

5. Transmission of data from experiments. This can be especially important in fault diagnosis during the data-taking phase of an experiment.

6. Tele-conferencing. The efficient management of large collaborative enterprises demands frequent exchange of information and views, leading to decisions on policy and design.

To achieve these goals, progress is necessary in the following areas:

1. Wide-Area Network Protocols

In the absence of internationally agreed standard procedures (protocols) for the different modes of transmission (text, program files, graphics, etc.), the high energy physics community is obliged to implement interim *ad hoc* solutions. This should be done with closer collaboration and coordination between the communities in different nations and regions, to allow greater 'transparency' to the passage of information across the boundaries between different systems. For example, in Europe there is the GIFT project to implement a file-transfer gateway linking four independent networks with different file transfer protocols: UNInet in Scandinavia, INSNnet in Italy, JANnet in the United Kingdom, and CERNnet.

At the same time every effort should be made to follow paths close to those which may eventually become internationally accredited (ISO) standards. Indeed the high energy physics community can, from its experience, make valuable contributions to the international study of these matters and perhaps even influence the outcome. This community in Europe is, through ECFA and CERN, contributing to the effort to establish international standards by collaboration with EEC study-groups and contacts with ESONE (European Standards Organization for Nuclear Electronics) and other bodies. Closer contacts would be desirable between the high energy physics communities in all the summit countries on these matters, leading to coordinated input to the international bodies charged with establishing standard protocols.

Governments should encourage speedy completion of this work, and especially agreements which would lead to early implementation of fully international networking (e.g., OSI – Open System Interconnection model of the ISO – International Standards Organization).

2. Transmission rates

The maximum rate of transmission widely available, (though on special telephone lines) is 9.6 k-baud (1 baud = 1 bit per second). This is adequate for modes 1 to 3 described above, but only marginally so for transmission of graphics, which requires the 64 k-baud digital transmission expected to become available soon.

Transmission of significant amounts of data from experiments requires speeds in the Mega-baud range, and Tele-conferencing requires the full bandwidth typical of television broadcasting. These two functions then depend on direct station-to-station transmission via satellite (6.3 M-baud)

3. Access

The principal obstacles to use of these advanced modes of communication by the high energy physics community are currently seen to be the reluctance of the national authorities responsible for communications to allow the full range of networking traffic to cross frontiers, and the very high related charges. The governments represented at the 'Summit' could take actions that would provide a direct and immediate stimulus to improved international collaboration by allowing the high-energy physics community to exploit internationally the full range of networking functions. In Europe ECFA and CERN have a goal of establishing a set of networking functions, HEPNET (of which GIFT is a part), which would be used across Europe, on both public and private networks, to link together the universities, institutes and laboratories. The success of HEPNET and its possible extension to link other regions depend on government support for the use of national communications systems in this way.

Turning to costs, the charges made for use of the present land lines become high as soon as national boundaries are crossed. This is already a serious inhibition for many of the universities and smaller institutes in Europe to use networking links even for the less demanding modes 1 to 3. The likely costs of satellite transmissions appear to be prohibitively high, and the advantages, especially in Tele-conferencing, can only be fully realized through frequent use. Therefore, if these facilities are to be widely used, they must be made available at reduced rates. The return would be seen in greater effectiveness in the use of the resources available to high energy physics, greatly enhanced scope for international collaboration in both the exploitation and development of accelerators, and some contribution from the high energy physics community to the development and assessment of modern communication technology (examples being the

STELLA project which was financed by the EEC, and the Japanese-USA network now being set up).

B. Standardization

In addition to the need for international standardization in communications technology, significant benefits for international collaboration would result from adoption of standards in the following areas:

1. Data-acquisition electronics

High-speed computer-controlled data acquisition is vital to high energy physics experiments. The CAMAC system is an example of a widely adopted IEEE standard first developed in the context of nuclear electronics. To meet the higher data rates from contemporary experiments a new standard, FASTBUS, is being proposed and will probably be widely adopted in high energy physics. As with CAMAC, FASTBUS is also likely to find many applications in other fields. Micro-processors are another area where some standardization may be possible.

2. Software

The development of software makes one of the greatest, and most often underestimated, demands on man-power. Efforts are being made to adopt standard programs as widely as possible, especially for tasks such as data base management. Much more should be done in this direction, but a necessary prerequisite is the greater facility for exchange of programs, and their up-dating, through the improved wide area networking mentioned above.

C. Recommendation

There are many benefits to be gained from increased use of modern communications technology, and by the wider adoption of standard procedures and equipment, in the fields of both detector and accelerator research and development. These are also areas that make contact with a broad range of other activities, so that the contributions made within our field could be of much wider benefit.

Because of the central importance of these questions to improvement in international collaboration, we recommend that a special technical sub-group be formed to make specific recommendations on communications, and particularly to address the relevant inter-regional aspects.

D. Communications sub-group

The terms of reference should include consideration of the following:

1. Standards for wide area networking in HEP.
2. Proposals for implementation of international networking for HEP (e.g., HEPnet and extensions).
3. The requirements for satellite links.
4. The current charging structure for international communications, in the context of use for HEP.

V. BROADENING THE BASE FOR HEP

Most of the R&D programs in accelerator and detector technology take place at the few major laboratories where the large HEP physics facilities are located. It would be very important to broaden the base for these activities for the following reasons.

1. Heavy commitments of the staff of the major laboratories with existing and planned machines make it difficult for them to carry out with all the desired vigor the many R&D tasks that are essential for future novel accelerators, possibly based on new principles, and for novel detectors that will be needed for more advanced physics experiments.

2. Smaller universities or technical universities are generally not heavily involved in this field. Their participation should however be strongly encouraged, because this would broaden the attack on many fundamental and technical problems present in the field. These problems are frequently of an interdisciplinary nature (computer science, plasma physics, quantum electronics, etc.), and the university structure is well-suited in principle to handle them. It is therefore likely that important contributions can be obtained through strong involvement of these institutions. Moreover, they constitute a rich source of young, well-qualified scientists and high-level technical staff, which is needed in order to insure that the field stays lively and dynamic. Universities will share in the benefits eventually obtained from this advanced technological research, and they may thus be induced to take a larger share in the fundamental aspects of HEP research.

3. Some countries where no HEP base exists at the present time may advantageously collaborate in HEP development programs of the future. This applies in particular to the rather numerous less-developed countries (LDC's) of adequate scientific and technological level, where international cooperation would provide highly specialized advanced training to their scientists and engineers who participated in these efforts. This involves work in many fields like computer science, microelectronics, superconductivity, material science, etc. The people trained in this way would be extremely useful after return to their home country, whether there exists a HEP base or not. International cooperation would be a significant contribution to the training of senior staff in certain advanced technological areas.

Despite the great need for a sound scientific basis in accelerator science, it appears that almost no universities or technical universities offer regular courses on the subject. This is one of the reasons for the relative lack of qualified young manpower in the field. These courses should be implemented and accompanied by theoretical and experimental research activities. Such work could conveniently be addressed, for example, to the many unsolved questions related to the new acceleration technologies described elsewhere. The research would usually consist of two major phases. In the first phase, most of the work would be done at the smaller institutions by their staff and graduate students. The funding for this, as well as the seed money necessary to set up the courses, should be provided by the domestic funding agencies. The second phase might require some special large equipment, such as high-power lasers or accelerators, that is available only at the major centers; this should be funded through an international cooperative agreement, which would determine the scope of the corresponding programs. There should also be an international mechanism for providing fellowships at the major centers for student training and for research performed by university staff in common programs.

One of the returns for the university and the home country might well be eventual industrial development of the results of the research activities. There are already some examples of this, as in the case of the development of a new method for producing high-field superconducting wire by a Dutch institute, which has been transferred to industry; and also the development of superconducting cavities by a German university which are now produced commercially.

Short-term schools on accelerators do already exist on a regional basis, and they are starting to be implemented on an inter-regional basis. International cooperation in this field is necessary because the spread of information and critical comparison of results is important for any future project. It would also be useful to provide funding for the participation of some people from non-HEP countries to attend these schools, especially for the LDC's.

The importance of HEP advanced techniques for highly qualified and motivated technicians from LDC's has already been stressed. Some local initiatives are already being taken in the US and in Europe in order to provide high-technology training for scientists and engineers from LDC's. Cooperative international action aimed at broadening this kind of training would be extremely valuable. The techniques of HEP are obviously essential if a country decides to develop a HEP research program, but even if this is not the case, one should notice that acclerators have uses in other fields such as in medicine, solid state physics, etc. More generally a high-level staff with sound training in advanced techniques through a first-class international collaboration would certainly be very valuable in a broad range of technical and industrial developments.

APPENDIX G

Agenda
for High Energy Physics
Summit Working Group
A. Borschette Convention Centre
36 Rue Froissart, Room 0-B
Brussels, Belgium
July 2 and 3, 1984

<u>July 2, 1984</u>

9:30 Opening Remarks: Dr. A. Trivelpiece, Working Group Leader (United States)

Review of Working Group Activities
London Economic Summit Statement

Acceptance or Modification of Agenda

10:00 Presentation: Dr. B. Richter, Director-Designate
Stanford Linear Accelerator Center

"Improving International Collaboration in High Energy Physics"

Report of the Technical Subpanel of the Working Group

Open Discussion

Acceptance of Report Recommendations

2:00 Status of Current Programs

Discussion of Future Working Group Activities

Proposal from the United States	Dr. A. Trivelpiece
Other Items	Heads of Delegation

Open Discussion Leading to Subpanel Charges

Development of Charges	Ad Hoc technical groups of delegates

<u>July 3, 1984</u>

9:30 Wrap-up Session: Dr. A. Trivelpiece

In which the technical groups report
back to the full Working Group

Meeting Attendance
Summit Working Group
on High Energy Physics
Brussels, Belgium
July 2 and 3, 1984

United States:	Dr. Alvin Trivelpiece, Working Group Leader Director, Office of Energy Research U.S. Department of Energy
	Dr. James Leiss Associate Director for High Energy and Nuclear Physics Office of Energy Research U.S. Department of Energy
	Dr. Leon Lederman Director Fermi National Accelerator Laboratory
	Dr. Burton Richter Director Stanford Linear Accelerator Center
	Dr. Jack Sandweiss Department of Physics Yale University
Canada:	Dr. Douglas Stairs, Head of Delegation Department of Physics McGill University
European Communities	Dr. Paolo Fasella, Head of Delegation Director-General Science Research and Development Commission of the European Communities
	Professor H. Schopper Director-General CERN
	Dr. Giorgio Brianti CERN
	Dr. Michel Paillon Principal Administrator Science Research and Development Directorate Commission of the European Communities

France:	Dr. Jules Horowitz, Head of Delegation Director Institute for Fundamental Research
	Mr. Pierre Lehmann Director of the IN2P3
	Mr. Joao Meyer DPHPE CEN-Saclay
	Mr. Perez-Y-Jorba Laboratories de l'Accelerateur Lineaire
Federal Republic of Germany:	Dr. H. Deyda, Head of Delegation Basic Research and International Cooperation Federal Ministry for Research and Technology
	Professor V. Soergel Chairman DESY Directorate
	Professor G. A. Voss DESY
Italy:	Dr. Nicola Cabibbo, Head of Delegation President, National Institute of Nuclear Physics (INFN)
Japan:	Dr. Tetsuji Nishikawa, Head of Delegation Director General, National Laboratory for High Energy Physics
	Professor K. Kondo Institute of Physics University of Tsukuba
United Kingdom:	Dr. Harry Atkinson, Head of Delegation Director, Science Science and Engineering Research Council
	Dr. Derek Colley Physics Department Birmingham University
	Dr. George Kalmus Rutherford Appleton Laboratory
Secretariat:	Mrs. Marilyn Smith Special Assistant to the Director Office of Energy Research U.S. Department of Energy

Agenda

Summit Working Group on High Energy Physics

Cadarache, France
January 12, 13, 14, 1985

Welcome by Host Country	Dr. J. Horowitz
Acceptance of the Agenda	Dr. A. Trivelpiece, Working Group Leader (United States)
Long-Term Planning	Dr. H. Atkinson, Subpanel Chairman (United Kingdom)
Subpanel Report	
Discussion	
Technical Collaboration	Dr. D. Stairs, Subpanel Chairman (Canada)
Subpanel Report	Dr. G. Brianti, Subpanel Member will present the report
Discussion	
Administrative Issues	Professor P. Fasella, Subpanel Chairman (European Communities)
Subpanel Report	Dr. J. Contzen, Director of Research for Science, Research, and Development will present the report
Discussion	
Drafting Conclusions Report	Dr. A. Trivelpiece
Drafting Progress Report for Bonn Summit Meeting	Dr. A. Trivelpiece

Summit Work Group High Energy Physics

Cadarache, France
January 13 and 14, 1985

Attendance List

France

Dr. J. Horowitz (Head of Delegation)
Director
Institute for Fundamental Research
Commissariat a l'Energie Atomique

Dr. Pierre Lehmann
Director, Science
Nuclear and Particle Physics
CNRS

Federal Republic of Germany

Dr. H. Deyda (Head of Delegation)
Basic Research and International Cooperation
Federal Ministry for Research and Technology

Professor V. Soergel
Chairman
DESY Directorate

Italy

Dr. N. Cabibbo (Head of Delegation)
President
National Institute of Nuclear Physics

Japan

Dr. T. Nishikawa (Head of Delegation)
Director General
National Laboratory for High Energy Physics

Mr. K. Kusahara (Observer)
Research Coordinator
Research Institute Division
Ministry of Education Science and Culture

United Kingdom

Dr. H. Atkinson (Head of Delegation)
Director, Science
Science and Engineering Research Council

Dr. J. Dowell
Professor of Elementary Particle Physics
Department of Physics
The University of Birmingham

United States

Dr. A. Trivelpiece (Head of Delegation, Leader of Working Group)
Director of Energy Research
Department of Energy

Mr. J. Mares
Assistant Secretary for International Affairs and
Energy Emergencies
Department of Energy

Dr. J. Leiss
Associate Director for High Energy and Nuclear Physics
Office of Energy Research
Department of Energy

Mrs. M. Smith (Secretariat)
Special Assistant to Dr. A. Trivelpiece
Department of Energy

Mr. J. Boright (Observer)
Science Counsul
American Enmbassy, Paris

European Communities

Dr. J. Contzen
Director for Science and Technology Policy,
Coordination, and Cooperation with Third Countries
Commission of the European Communities

Dr. V. Soergel
Director General
CERN

Dr. G. Brianti
CERN

Dr. M. Paillon
Science and Technology Policy Division
Commission of the European Communities

CERN 84-14
11 December 1984

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ECONOMIC UTILITY
RESULTING FROM CERN CONTRACTS
(SECOND STUDY)

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GENEVA
1984

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CONTENTS

SUMMARY

This report describes the methods and the main results of a study which aimed at the quantification of Secondary Economic Utility, defined as the sum of increased turnover and cost savings, generated in European high technology industry due to orders placed by CERN during the period 1973-82. The study was similar to one made ten years ago, covering the period 1955-78 (see Ref.[4]). However, based on the experience gained during the first study, a general quantification model and improved sampling and extrapolation methods were used this time.

Managers in 160 firms out of a total of 519 high technology suppliers to CERN were interviewed. They estimated their Economic Utility using the general quantification model presented to them during the interview. As in the first study they were asked to give, if possible, five-year utility forecasts; and it emerged during the study that when managers feel able to make forecasts, these are, on average, reasonably accurate.

If the utility obtained for the firms interviewed is extrapolated to the total of 519 high technology suppliers to CERN, the resulting total utility for the period 1973-87 expressed in 1982 prices amounts to 4800 millon Swiss francs (where the values for 1983-87 are based on forecasts). The extrapolation error is about ±600 million Swiss francs. During the period 1973-82 CERN's purchases from the 519 firms amounted to 1380 million Swiss francs.

It is estimated that about 15% of the Economic Utility generated since 1973 has come from purchases made prior to 1973. Correcting for this reduces the total Economic Utility to 4080 million Swiss francs for purchases made since 1973. The corrected utility/sales ratio is 3.0; which means that one Swiss franc spent by CERN in high technology generated three Swiss francs of Economic Utility. The overall cost of the Organization during 1973-82 was 6945 million Swiss francs, which gives a value of about 0.6 for the ratio of the corrected utility to total CERN cost. It may therefore be stated that, by 1987, CERN's high technology purchases made in 1973-82 will have generated Economic Utility amounting to about 60% of the overall cost of CERN during the same period.

A comparison of results obtained in the first study with those of this study indicates that CERN's "utility creating power" is essentially the same as ten years ago, and it also appears that the high technology branches supplying CERN are suffering less from the present economic difficulties than other sectors of industry.

CHAPTER I

BACKGROUND TO THE STUDY

About 30 years ago, a number of European countries collaborated to establish CERN in order that Europe could regain its place in the forefront of particle physics research. CERN has since built a range of sophisticated accelerators and research equipment to fulfil its mandate. Considerable resources have been necessary to accomplish this, and CERN has in consequence found itself assuming a technological and economic role in Europe in addition to the important scientific results it has achieved.

Economic and cultural effects of fundamental sciences, and the processes by which they create direct and indirect benefits to the society, have been reviewed from time to time, Refs.[1] and [2], for example. The primary function of CERN is to carry out "very basic research" in particle physics, and the direct product this research work is increased scientific knowledge or "culture", which may in the long term give rise to innovation. An additional direct effect concerns CERN's educational role in the training of physicists and engineers. The quantification of the economic value of these direct effects would be extremely difficult, if not impossible. However, CERN buys large quantities of high technology equipment and the firms fulfilling these orders often observe short-term (several years) economic advantages as a result of collaboration with CERN.

A first study, made in 1973-1975, attempted to quantify these secondary economic effects generated by CERN. In this study about 130 firms which had contracts with CERN were interviewed and asked to quantify such effects. The study verified that CERN, with its purchases of high technology equipment, often causes positive changes in the turnover and the production techniques of its suppliers, and that managers are prepared to elaborate and communicate quantitative information related to these effects. Details of this first study are published in Refs.[3] and [4]. Similar results were obtained during studies which quantified secondary economic effects created by the European Space Agency, Refs.[5] and [6].

Since the time when the first study on the quantification of secondary economic effects resulting from CERN contracts was made, the methodology of quantifying the economic effects has been refined, Europe's economic situation and its technology have undergone significant changes, and CERN itself and its relationships with industry have changed. CERN now spreads its orders over a greater number of firms than it did in the past, the number of other European and national organizations buying high technology equipment has increased; and European industry has been able to close some of the technological gaps which existed 15-20 years ago between Europe and the United States. A study of the resulting change in the nature of the economic effects is clearly of interest. In addition, the first study took place at a time when the effects being measured had arisen mainly during the construction period of the Intersecting Storage Rings (ISR). The effects arising during the construction period of the Super Proton-Synchroton (SPS) were, however, only partly covered

by forecast values given by industrial managers. For all these reasons, it was decided to make a second study.

This paper reports results of the second study, carried out between 1982 and 1984. Improved methods for the quantification of secondary economic effects, as compared with those used in the first study, have been applied; in particular, a general quantification model has been developed to achieve the quantification of these effects in a more systematic and rigorous way. In addition, greater efforts have been made to define the total family of suppliers of high technology equipment to CERN, and to obtain a representative sample of these suppliers. This allowed the extrapolation of the results obtained for the sample to the complete set of firms from which the sample was taken.

CHAPTER II

ECONOMIC EFFECTS OF RESEARCH CENTRES

II.1 GENERAL DESCRIPTION OF THE EFFECTS

The principal aim of research centres is the generation of new knowledge, part of which, depending on its nature, will be used sooner or later as input in the innovation process at the end of which stand new or improved products or services. Beyond this, however, research centres may have important economic effects within the whole network of the economy. These effects may be essentially divided into three categories.

i) PRIMARY ECONOMIC EFFECTS: These result from the primary aim of the research centre when the centres produce innovations themselves, such as new energy sources, telecommunications satellites, etc.

CERN's primary aim is very basic research in particle physics and practical applications of its results can rarely be foreseen. Therefore, economic effects resulting directly from research done at CERN will hardly occur in the foreseeable future. However, the importance of long-term basic research for future technological progress is well known and has been discussed in some detail by Lederman, Refs.[1] and [2], and in the IIT report, Ref.[7].

ii) SECONDARY ECONOMIC EFFECTS: It is generally found that a major part of the scientific equipment necessary for carrying out the research is supplied by industry. Often the specifications and requirements are beyond the "know-how" currently available and thus represent a challenge to the manufacturer. Positive effects, such as new products, quality improvements, productivity increases, etc., arising from this challenge may be called the "Secondary Economic Effects" of research institutes, Ref.[8]. They are also sometimes called "spin-off" or "fall-out".

The present CERN study is confined to these secondary economic effects. A quantification of all the secondary economic effects resulting from CERN is probably impossible. It was therefore necessary to select certain main effects which could be quantified, and for which industry was prepared to provide data. The description of these main effects, which we call "Economic Utility", is given in the next section.

iii) MULTIPLIER EFFECT: This occurs with all public investments that create additional demand for goods.

It is because of the multiplier effect that the direct spending of CERN's material budget in the member states, and the spending by CERN personnel in the region where they live, also stimulate the economy and create employment. These effects are not quantified in this study, but have been evaluated for DESY in Hamburg, Ref.[9]. The Geneva Statistical Office, Ref.[10], has studied the effects of the international organizations in Geneva.

II.2 ECONOMIC UTILITY

In order to fit the secondary economic effects into a larger framework we may use the "surplus" concept developed by Massé, Ref.[11], which is described in more detail in Appendix A. This concept considers all the economic agents (employees, shareholders, customers, suppliers and the state) in relation to the firm. It defines the gains, positive or negative, which these agents realize as a result of changes in industrial production. The sum of these gains, assuming it is positive, is called the "surplus" by Massé, who defines its value by comparing different years. But we can also define the surplus by comparing two different situations during the same time period. We can, for example, compare a firm which is in business contact with a research centre such as CERN, and the same firm without this contact. The comparison of these two situations may also show a gained surplus.

As shown in the Appendix A, the parts of the gained surplus, as reported by managers in firms which have been influenced by a research institute such as CERN, are increased turnover on the sales side and cost savings on the procedures and production side. We call the sum of these two effects "Economic Utility" so that

Economic Utility = Increased Turnover + Cost Savings.

It is this part of the secondary economic effects due to CERN which is quantified in this study, and which was also quantified during the first study.

CHAPTER III

ECONOMIC UTILITY RESULTING FROM CERN

III.1 THE ECONOMIC UTILITY CREATION MECHANISM

Economic utility is stimulated by CERN through its purchases from industry. Indeed much of the equipment needed by CERN poses new problems, either by the technical specifications, or even by the sheer volume of complicated non-standard goods (e.g. hundreds of high-precision electromagnets or high-performance vacuum pumps) which are necessary for the building of an accelerator or related experimental equipment.

Firms which meet the challenge of such deliveries may afterwards be able to offer and sell new or improved goods to their other customers. Thus sales increases may be due to the following mechanisms:

i) NEW PRODUCTS: Firms may be led to market new or improved products as a consequence of the acquisition of new technology they have developed for, or together with, CERN. Also the volume of orders placed by the Organization, its non-competitive relation with industry, and the possibility of monitoring the performance of equipment delivered to CERN, may incite a firm to develop new products.

ii) MARKETING: The success of a product depends finally on its sales on the market. CERN's criteria for selecting products are known to be rigorous, and CERN is obliged to choose its suppliers on the basis of price for well-defined specifications. Considerable efforts are devoted to comparing products in order to choose the most suitable ones, and other customers may profit from this work by following CERN's choice. Further, material delivered to CERN is subject to strict performance control when in operation, sometimes for very long periods. Firms may refer to these facts in order to persuade other customers to buy their goods.

(It might be argued that a CERN supplier which increases its share of the market does so at the expense of its competitors; and that, from a European point of view, there might be no positive effect at all. This argument would be correct only in a market with conventional goods and a constant volume. We are dealing with markets which have high growth rates (electronics for example), and/or with products which change constantly due to rapid technological evolution. CERN buys products of the highest quality adapted to its purposes and at the lowest price. The resulting higher turnover forces the competitors of the CERN suppliers to improve their products, to the benefit of other customers. This is an efficient mechanism for keeping European industry abreast of overseas competition).

iii) QUALITY: Many firms producing in high technology fields sell their products primarily on the basis of quality. Contributions to quality represent, for these firms, an important element, since it permits them to maintain or improve their place in the market. CERN's quality requirements are often higher than that initially offered by the firms, but not so

high as to lead to products which are overpriced and hence find no other customers. CERN therefore has an appreciable effect, not only as a "quality standard", but also through its capacity to help overcome technical problems when they arise.

iv) MAINTENANCE OF PRODUCTION CAPACITY: Some areas of high technology are still awaiting a breakthrough in the marketplace. In the meantime, orders from research centres, such as CERN, may assure the survival of some production capacity related to such areas, thereby contributing to Europe's technological independence. CERN orders may generally help firms to survive difficult periods when other orders are low.

Cost savings may result directly from the CERN-industry connection if, for example, a firm learns something new as a result of an order from CERN. This may occur by fulfilling the Organization's requirements, or through contact with its engineers who showed how to improve a particular production process, or by using research and development results from CERN. Indirect cost savings may result from increased sales to - or stimulated by - CERN as described above.

There are occasional losses resulting from the relation between CERN and industry, or as a side-effect of generating utility. These have to be taken into account when economic utility due to CERN is quantified. This fact is covered by the general quantification method which is described in the next section.

III.2 THE QUANTIFICATION METHOD

Economic utility caused by research establishments is actually produced in, and by, industry and this is where the data have to be collected for its quantification. They are in most cases, not readily available and are often confidential. Hence some conditions must be fulfilled in order to carry out a utility study successfully. First, the information must be collected by means of personal interviews. Many managers are prepared to provide information orally which they would not convey in writing. The mechanisms of utility creation are too complex to be covered entirely by a questionnaire, which could lead to misunderstandings. Second, quantification models have to be developed, which are sufficiently concise to be explained within the limited time available during the interview, and which are sufficiently powerful to cover the multitude of cases which occur.

Based on the experience gained in the first study, a general quantification formula for the quantification of economic utility due to CERN was developed for the new study. The basic ideas which underly the formula are given below.

For simplicity, the explanation of the basic ideas is limited to an example of the quantification of increased turnover utility. The general case including the quantification of cost savings utility is given in detail in Appendix B.

We assume that there are basic activities in a firm which essentially cause economic results such as turnover. Such activities, which are shown in Figure 1, are mainly related to the following: new products, marketing, research and development, production techniques, management procedures, quality standards, pricing. A firm may, for instance, say that 10% of its total turnover is due to its marketing efforts and 15% is due to activities which ensure good quality. Suppose now that the firm estimates that the influence of CERN has led to a 20% improvement in its marketing to other customers and helped to improve quality by 10%. We then conclude that $100 * 0.1 * 0.2 = 2\%$ of the total turnover is due to CERN's influence on marketing, and in addition, $100 * 0.15 * 0.1 = 1.5\%$ of the turnover is due to CERN's impact on quality. Generalizing this idea, managers can put percentage figures on the various activities of their firms and on CERN's influence on these activities.

purchases

It is, however, clear that often only some part of the total turnover of a firm is influenced by CERN (in Appendix B this is called "CERN Relevant Turnover"). From this relevant turnover,

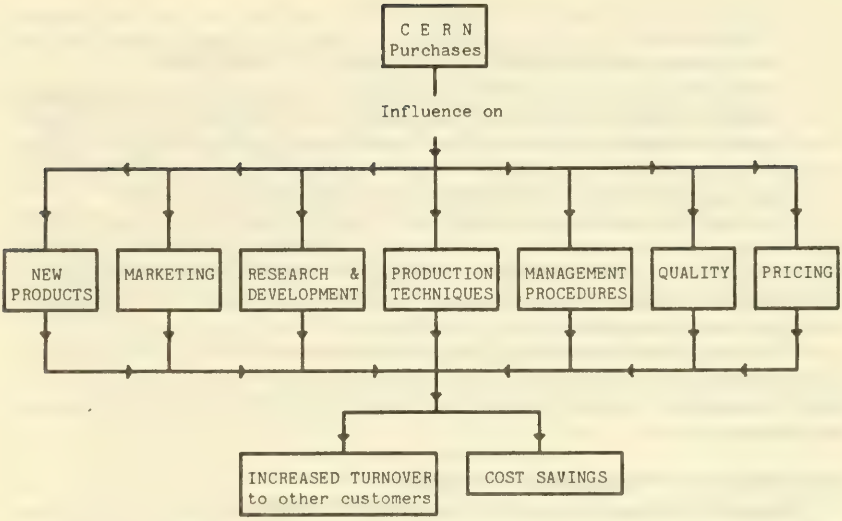

Figure 1: Principal secondary economic effects resulting from CERN.

the firm's direct sales to CERN must then be subtracted and the remainder multiplied by the above-mentioned percentages to give the increased turnover generated by CERN. Finally, any financial losses due to CERN, and any opportunity costs, or investment costs necessary to bring about the utility must be subtracted to obtain the increased turnover utility.

Possible cost savings are calculated in an analogous manner.

Since prices and influence factors are time-dependent, utilities are estimated by industrial managers in financial periods, each covering one year. As in previous studies, they relate not only to past events but also include, whenever possible, forecasts for the next five years.

III.3 THE SAMPLE OF FIRMS

CERN buys from approximately 6000 suppliers, about 10% of whom sell high technology goods. As it was considered necessary to make personal interviews in order to obtain accurate quantification data, and as the resources in time and money available for the present study were sufficient for about 170 firms to be interviewed, only a sample of the high technology suppliers of CERN could be considered in the present survey.

The first problem was to select the high technology firms from the total of 6000 CERN suppliers. Computer tapes giving details of CERN payments to firms for seven years during the period 1973 to 1981 (1974 and 1979 tapes were not available) were used for this purpose.

About 90% of the firms on the tapes are not high technology suppliers, and these were eliminated in two steps. Many were excluded by a decision to consider only those firms which had sales to CERN equal to or greater than 100000 Swiss francs in at least one of the seven years covered by the tapes. The resulting list contained more than 1200 firms, and checks revealed that only a small fraction of high technology suppliers was lost this way. By checking the firms remaining on the list individually, and eliminating those not supplying high technology equipment, a final number of 519

high technology firms remained. The results from the sample of firms interviewed have been extrapolated to obtain valid figures for the whole family of 519 high technology suppliers.

The family of high-technology firms was divided into two classes: firms which had participated in the first study (named "old" firms), and the rest (named "new" firms). It was decided to take about one quarter of the total sample from the "old" firms in order to be able to compare the results with those of the first study and to analyze the validity of the forecast utility values from the first study. This gives an over-representation of "old" firms; but, since a random sample was taken separately from both the "new" and the "old" firms, these two samples are representative each of its own group. In each group a stratified sample was taken, where the stratification (grouping) was made according to five industrial categories (see Table I) and two levels (less than, or greater than, one million Swiss francs) of the firms' total sales to CERN during the time-period being examined.

Apart from the grouping mentioned above, seven "old" firms were selected for the training of the interviewers. The selection of these seven firms was not done by random selection, and therefore the results for these firms were not used for the extrapolation to the whole group of "old" firms.

III.4 THE INTERVIEW PROCEDURE

The data were collected between May 1982 and June 1984. The group making the interviews consisted of the seven authors of this report coming from various disciplines. Each interviewer was provided with information concerning the firms, such as order volume and the nature of the material delivered to CERN. Before the interview, discussions were held with one or more CERN staff who had had technical contact with the firm. The most appropriate top-level manager in the firm was then contacted by telephone and asked if the firm would agree to participate in the study, and an appointment was fixed. In rare cases, where no appointment could be arranged, the interview was carried out by telephone.

To avoid misunderstandings, the interview was carried out, whenever possible, in the language spoken by the industrial manager. Interviews began with a short review of the first CERN Economic Study and stressing the confidentiality of any information provided by the manager, followed by a review of past and/or present contracts with CERN. Sales figures to CERN were checked, as well as the type of goods supplied, these figures being broken down, where necessary, by production branch of the firm. The type of utility created by the collaboration was determined using the quantification model. In some cases, where the utility was due to specific contracts obtained as a result of CERN influence, the manager provided absolute values of utility. Other information obtained, where possible, included distribution of surplus, origin of goods, comments on CERN's purchasing procedures, creation of employment, etc. Where a firm had participated in the first study, the previous forecasts for the first part of the period now being examined were compared with what really happened. It was helpful if the same manager could be seen on both occasions, as personal knowledge and memory play important roles in the estimation process, but, because of the effects of staff changes in ten years, it was in fact unusual to be able to do so.

During the interviews it was often possible to meet the director of the firm and/or the directors of various branches (technical and marketing directors), to visit the production lines, and to gain a better understanding of where problems had arisen, or could arise, when dealing with CERN. It proved necessary from time to time to explain the essentials of CERN's Financial Rules and related purchasing procedures, and to explain the way these rules have been laid down by the Council and subsequently checked for correct application.

A report, used exclusively by the members of the study group, was prepared after each visit made, and the information obtained was summarized in tables from which the data were entered into a computer for subsequent analysis.

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CHAPTER IV

QUALITATIVE RESULTS

IV.1 GENERAL REMARKS

The industrial managers who were interviewed provided estimates of the increased turnover and cost savings due to the influence of CERN, but only occasionally gave information concerning the way in which these turnover increases have been achieved.

Increased turnover has in some cases led to the creation of employment, but many firms will probably have taken advantage of a certain amount of unused resources, and this has avoided the laying off of personnel.

The evaluation of the cost of increased turnover and the full quantification of the creation and maintenance of employment would require further investigations among the firms concerned.

Risk is a major obstacle to industrial innovation. When dealing with CERN the risk inherent in breaking new ground is likely to be less than when dealing with other customers. CERN can often help in solving technical problems, and failures are certainly not exploited by CERN to harm the industrial partner. After all, the only thing of interest to CERN is to obtain goods with the required quality within the time specified. All performance data on material delivered are available to the interested supplier, and this information is successfully used by some firms to save costs and/or to open new markets.

IV.2 IMPRESSIONS OF THE INTERVIEWS

Some interviews started cautiously, especially where CERN had not placed any orders for some years. On a number of occasions, although there appeared to be no probability of finding utility when the firm was first approached, positive results were nevertheless obtained during the interview.

In the branches where technological development was pushed by CERN, many firms appreciated the information and help given by CERN technical staff. This often helped them to overcome major problems which had not been foreseen in advance.

Marketing is an important factor, especially in the case of small firms which had not previously exported outside their own countries. CERN has succeeded in helping several such firms to initiate their export trade. The mere fact of having sold to CERN may be an important sales argument, although this was sometimes difficult to quantify.

CERN's quality requirements have helped some firms to penetrate overseas markets, or to be more competitive against overseas suppliers on European markets. In one or two cases, the quality requirements had a negative effect, because they were much above the level required by other customers. As expected, the CERN influence was acknowledged in connection with research and development and quality improvement. Quality problems were sometimes seen to have produced

changes in management procedures and/or structures, although quantification of the resulting utility was not always possible.

During the interviews with firms which had incurred losses on CERN contracts it became clear that this often resulted from an under-estimation of the production costs. Some interviews also showed that firms may offer special conditions to CERN in order to have, or maintain, CERN on their reference list. The cost of this can be absorbed if the technology learned from CERN contracts is used to satisfy other customers or to introduce new products in the market; but difficulties may arise when the expected openings in the market do not occur.

IV.3 EXAMPLES OF CERN-GENERATED UTILITY

CERN-generated economic utility seems to grow on soil of all kinds, provided that at least one of several conditions is fulfilled.*) Some of these were found to be:

- the firm is active in advanced technology;
- a good professional relationship exists between CERN staff and staff in the firm with sufficient executive power;
- the marketing manager is aware of the fact that, for some potential customers, CERN is a good reference;
- the staff responsible for the firm's quality control have sufficient influence;
- the firm makes an effort to satisfy CERN's requirements, without necessarily making a profit while doing so.

The following examples illustrate these points:

i) TURNOVER INCREASE: Several European firms are fighting for a share of the high- and ultra-high-vacuum market. Their major sales argument is based on improved performance of the equipment offered to their customers. However, the development of a new or improved product is expensive and therefore risky. Under these circumstances, the large CERN projects with their requirements for a comparatively large number of units have reduced the risks considerably; and CERN has played a significant role in the firms' decisions to take the risk. CERN has significantly contributed to the breakthrough of several products on the market, and the firms in question were able to quantify CERN's contribution to the corresponding sales. The net result of this is that the European vacuum industry is well placed compared to the overseas competition.

ii) FIRM CREATED DUE TO CERN: A small firm specializing in precision mechanical components was set up about 10 years ago with the idea that the firm would be able to sell a reasonable percentage of its production to CERN. The firm was successful, and has regularly sold to CERN, whose influence on the success of the firm has remained at the same level as at the time the firm was created. At the beginning of the collaboration the owner of the firm had to develop special metal alloys to satisfy the CERN specifications. This has enabled the firm to remain competitive both on the home and export market, so that, when economic difficulties resulted in a drop in the home market, the firm was able to increase considerably its exports to other European countries.

iii) CERN AS A TESTBED: CERN may serve as a long-term testbed, since all performance data on material delivered are available to the interested supplier. This has been particularly true for suppliers of photomultipliers, and other special kinds of tubes; and especially

*) Even if some or all of these conditions are satisfied, there is no guarantee that utility will be created, owing to the many existing obstacles to successful technology transfer or to unforeseen market developments.

in computing and related fields. Computer manufacturers test computers, computer systems such as networks, and software, extensively at CERN, where they benefit from the "know-how" and long-standing experience of CERN's experts. In particular, some firms test electronic equipment for reliability and performance at CERN before putting it on the market.

iv) MAINTENANCE OF PRODUCTION: Among the problems of managing a shipyard is that of irregular production levels. One shipyard has on two occasions succesfully made bids for CERN contracts which enabled the yard to maintain its production level - and of course its work force - during slack times in its normal work of ship construction and repair.

v) INTER-COMPANY COLLABORATION: A small firm, which has supplied CERN with standard, but specialized, hydraulic equipment for about 15 years, entered into a commercial collaboration with several large firms because of contacts made at CERN. As a consequence of this collaboration the smaller firm's components are now standardized with the products of the larger firms, resulting in a large increase in turnover and exports to other countries.

vi) COMPLEX UTILITY WITH MANY INFLUENCE FACTORS: A firm was created more than ten years ago to produce precision mechanical products with a few employees. Three years after its creation it obtained its first CERN contract for mechanical components for electronic equipment which has since been widely used outside CERN. In order to keep abreast of competition and to be accepted as a CERN supplier over the years, the firm has constantly had to improve the precision and quality of its products. It did so by using the CERN specification as a sort of standard. It further successfully used the reference to CERN sales in order to acquire other customers, first in research, and later in other markets such as television, railways, subways, etc. A few years ago it undertook a major internal re-organization in order to increase productivity - a risk it was able to take because of the CERN orders and the resulting utility. Approximately half of this CERN-created surplus was re-invested, and the remainder used in equal parts to increase salaries, reduce prices and pay taxes. Furthermore, CERN has created or maintained, by its contracts or the related CERN-generated utility, a number of jobs within the total workforce.

vii) COST SAVINGS: A large electronics firm received an order from CERN for amplifiers which enabled the company to maintain its production levels when other orders were low. A certain amount of development work was required in order to satisfy the special needs of CERN, leading to cost savings which were used by the company to reduce sales prices.

viii) INNOVATION AND QUALITY: The innovations and/or quality improvements resulting from CERN contracts are often applied in fields which have no direct connection with high-energy physics. For example, the strict and complicated requirements of CERN concerning the optical and ageing qualities of light guides and scintillators has enabled one firm to develop products for solar energy applications. Since the technologies necessary to obtain the required optical properties of solar panels in production quantities are already known to the firm, it expects to be able to enter the market - which is only just beginning to expand - with a lead over its competitors. In this case it was still too early to estimate the full amount of CERN-generated utility.

ix) CERN AS REFERENCE: Being a CERN supplier can often be a useful reference for firms. In one case a firm making cooling equipment for CERN was able to gain admission to a trade association and, as a result, was able to obtain an increased number of contracts. In another case a firm building transformers used the fact that it was a CERN supplier to support its request for an international licence for certain products.

x) NEGATIVE EFFECT: CERN's quality requirements do not always have a positive effect on industry. In one case, the rigorous technical requirements of a CERN specification influenced a firm making electrical equipment in deciding to change its general assembly line procedures. The firm later discovered that these changes had resulted in a decrease in productivity.

CHAPTER V

QUANTITATIVE RESULTS

V.1 QUANTITATIVE RESULTS OF THE SAMPLE

It must be emphasised that (as was the case in the first study) the quantitative estimations of the CERN-generated utility were made by the industrial managers and not by the CERN interviewers. In case of doubt, the lowest figures were always taken.

Between May 1982 and June 1984, 166 European firms were interviewed, and 160 were able to provide useful information concerning utility. Of these 160 firms, 55 had no utility or could not quantify admitted utility, and 6 had made losses on CERN contracts which exceeded utility.

The period covered by the study runs from 1973 to 1982 for the firm's sales to CERN, and from 1973 to 1987 for utility created by CERN. Previous studies on utility showed it was possible to obtain utility forecasts for about five years into the future. However, this time, because of the present economic uncertainties, managers were often very reluctant to give such forecasts, which were nevertheless obtained, for at least one year ahead, from 78 firms. The five-year forecast period until 1987 was therefore maintained in order to give results which are comparable with the previous study, but it is clear that the utilities reported for the later part of this period are under-estimated (see Figure 2).

Between 1973 and 1982, CERN spent 748 million Swiss francs*) with the 160 firms of the sample which provided information, and these firms reported a utility of 3107 million Swiss francs for the period 1973-1987. The utility arising from increased turnover amounts to 2983 million Swiss francs and utility from cost savings is 124 million Swiss francs.

It should be remembered that direct sales to CERN have been deducted from the increased turnover utility, and that values are net, i.e. opportunity and other costs, and any losses due to CERN, have also been deducted. These data represent a lower limit of the utility actually generated by CERN, for the following reasons. First, it is the impression of all the interviewers that there is no systematic bias which would lead firms to inflate utility figures to please CERN or the interviewer. Second, it is possible that the manager interviewed may not have been aware of certain utility situations, or he may not have been in his present position long enough to have experience of the whole period under review. Third, there remain some utilities which managers were sometimes unable to quantify, particularly the reference value of being a CERN supplier.

Figure 2 shows the histogram of the interviewed firms' yearly sales to CERN and the resulting yearly created utility. The corresponding accumulated values are shown in Figure 3.

The SPS project lasted from 1971 to 1978 with payment of invoices extending into 1979. SPS sales appear to have produced their utility with a delay of a few years. The values shown for the period

*) Financial data in Chapter 5 are expressed in constant 1982 prices (i.e. corrected for inflation).

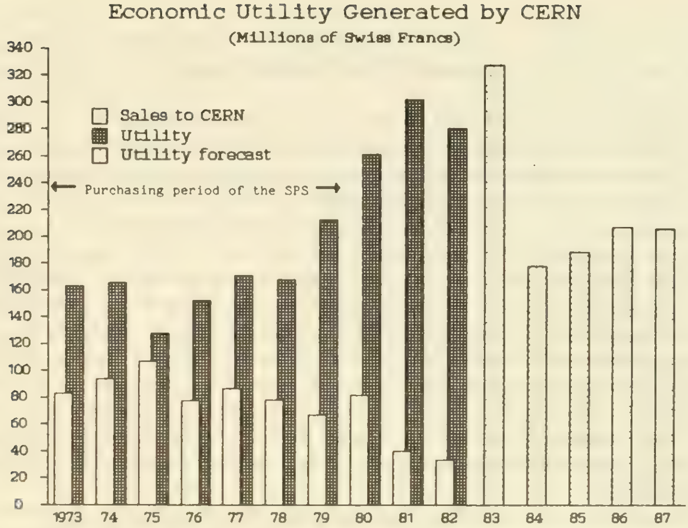

Figure 2: Yearly sales and yearly utilities from 160 firms interviewed.

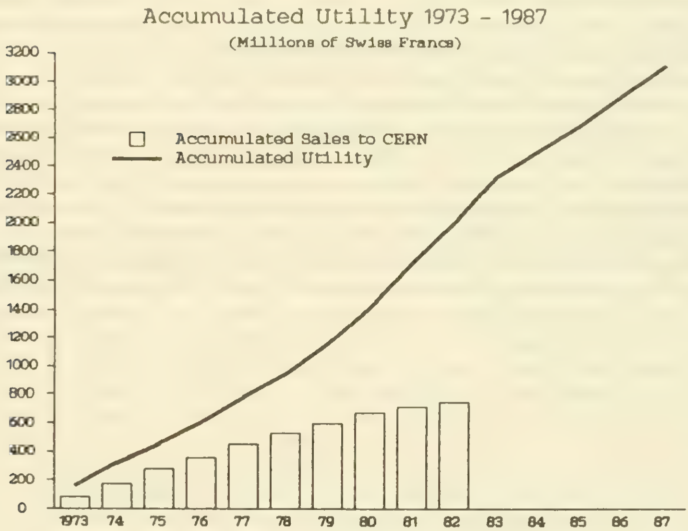

Figure 3: Accumulated sales and utilities from 160 firms interviewed.

1984-87 are comparatively low mainly because only about half of the firms interviewed made forecasts.

The utilities found for the various industrial categories are given in Table I.

Table I: Breakdown of Sample Data (160 firms) by Industrial Category

	Electronics, Optics, Computers	Electrical equipment	Vacuum, Cryogenics, Super-conductivity	Steel and Welding	Precision mechanics	Totals
Net utility (MSF)	1576	877	355	225	74	3107
Corrected utility* (MSF)	1340	745	300	190	65	2640
Losses (MSF)	3.7	5.4	5.3	0.4	0.2	15.0
Sales investigated (MSF)	220.1	359.2	101.3	35.8	31.2	747.6
Corrected utility/sales ratio	6.1	2.1	3.0	5.3	2.1	3.5
Number of firms interviewed	57	46	22	16	19	160
Number of firms without utility	12	19	8	8	8	55

* Corrected utility equals 85% of net utility, for explanation see Section V.2.

Because of the complexity of modern European industry, it is very difficult, if not impossible, to determine exactly which country benefits from the utility generated. This is particularly true for multinational suppliers. Therefore it has not been possible to make any breakdown of the information by country.

A part of the increased turnover making up the utility consists of sales to the high energy and nuclear physics market. Although it was difficult to obtain reliable information on this for the full period of the study, reasonably accurate values obtained for 1982 showed that only 24% of CERN-generated increased turnover consisted of sales to the high energy and nuclear physics market. Indeed, CERN's purchases have stimulated technological improvements in fields which are not related to high energy and nuclear physics such as, solar energy, electrical industry, railways, computers and telecommunications.

V.2 EXTRAPOLATION OF THE SAMPLED DATA

The extrapolation of the utility obtained for the random sample to the total family of firms from which the sample was taken was made using the group averages. A few of the firms interviewed reported utilities which were noticeably higher than the utilities of other firms in their group, and although these cases (outliers) could be explained, they were not considered to be representative. They were therefore excluded from the computation of group averages, and hence not used for the extraplolation.

Between 1973 and 1982, CERN spent 1379 million Swiss francs with the 519 high technology firms, and the total utility for the period 1973-1987 obtained by extrapolation amounts to 4796 million Swiss francs. Errors can occur in the extrapolation process from two sources: errors in estimating the group averages, and errors due to the difficulty of assigning multi-branch firms to the correct group. This extrapolation error (99% confidence interval) has been calculated to be ±623 million Swiss francs.

When comparing the 3107 million Swiss francs of utility for the 160 firms to the 1689 million Swiss francs of extrapolated utility for the remaining 359 firms, two points have to be taken into account. First, the sales to CERN by the firms interviewed already represents 57% of the total high technology sales to CERN. Second, the outliers contributed strongly to the utility of the interviewed firms but did not contribute to the extrapolated values.

Assuming that the utilities of the years 1973-75 are essentially the result of CERN orders prior to 1973, the utility corrected for this effect is about 85% of the net utility. The corrected utility/sales ratio then gives a measure of the utility created by CERN's high technology purchases made during the period 1973-82. For the sample this ratio is 3.5, which compares well with the ratio of 3.7 found last time.*) The overall (after extrapolation) corrected utility/sales ratio becomes 3.0.

Table 2: Breakdown of Total Data (519 firms) by Industrial Category

	Electronics, Optics, Computers	Electrical equipment	Vacuum, Cryogenics, Super-conductivity	Steel and Welding	Precision mechanics	Totals
Net utility (MSF)	2638	1205	471	300	182	4796
Corrected utility* (MSF)	2245	1025	400	255	155	4080
Sales (MSF)	537.4	472.1	152.9	104.6	111.9	1378.9
Corrected utility/sales ratio	4.2	2.2	2.6	2.4	1.4	3.0
Number of firms	189	130	34	65	101	519

* Corrected utility equals 85% of net utility, for explanation see Section V.2.

*) This ratio is based on data expressed in constant 1977 prices, which explains the difference to the ratio published in Refs.[3] and [4], which was based on data expressed in current prices.

Table II gives a breakdown, by category of firm, of the extrapolated utility generated by CERN in the total family of 519 high technology suppliers. Figures 4 and 5 show these data in graphical form.

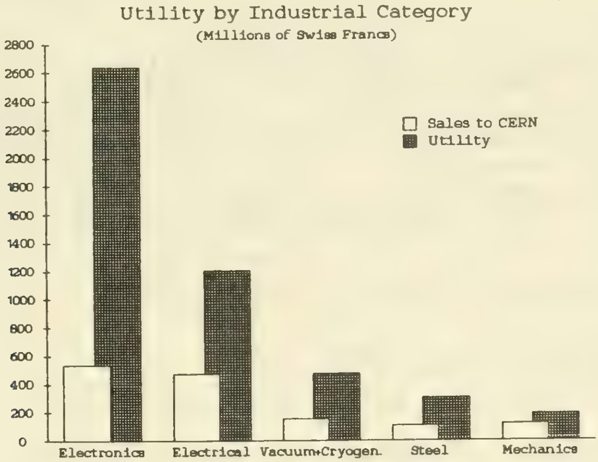

Figure 4: Total sales and total utilities from 519 high technology suppliers, broken down by industrial category.

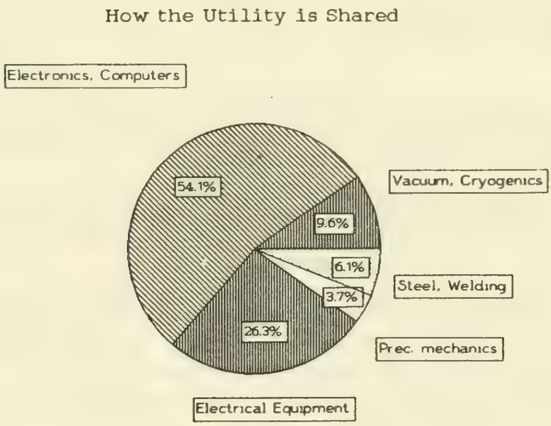

Figure 5: Total utility from 519 high technology suppliers, showing the contribution by industrial category.

The total cost of CERN in 1973-82 was 6945 million Swiss francs. The corrected utility/total cost ratio is therefore 0.85 * 4796/6945 = 0.59. Remembering that the firms interviewed have tended to provide low estimates of the probable actual utility, it may be stated that, by 1987, CERN purchases (high technology goods only) made in 1973-82 will have generated utility amounting to at least 59% of the total cost of CERN during the years 1973-82.

V.3 FORECAST VALUES AND ACTUAL EVOLUTION

During the first study most of the firms interviewed provided forecasts for the period 1974-78. About forty of these firms were selected by the random sampling process to be interviewed again this time, and they were questioned on the actual evolution of the utility during the forecast period. Out of these firms thirty-six provided data which could be compared to their previous forecasts.

This comparison showed that many firms actually realized utilities which were close to their forecasts, although in several cases the forecasts proved to have been too high or too low. This can be explained by:

- turnover of the firm different to the forecast,
- CERN effects coming earlier or later than expected, or not at all,
- losses due to CERN which could not have been foreseen,
- CERN influence on the firm different to the forecast,
- person interviewed unable to remember everything that happened ten years ago.

Out of the 36 firms, 21 had forecast utilities which turned out to be too high, and 15 forecasts which were too low. In spite of these variations, the total utility actually realized was within a few percent of the total utility forecast. In order to find out whether, on average, this difference between the forecast and the realized utilities was statistically significant, tests (t-test and signed rank test) for both the differences of the utilities and the differences of the utility/sales ratios were applied. None of these tests revealed a significant difference between the forecast and the actually realized utility values. We have therefore no reason to reject the hypothesis that managers can, on average, give correct utility forecasts.

Acknowledgements

We acknowledge the kind collaboration of the persons interviewed in the participating companies, without which this study could not have been achieved.

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Even though we made use of computerized purchasing records, much other vital information was supplied by members of the Finance Department, and for this we are most grateful.

Our thanks go to the CERN scientific and technical staff who provided us with details of the orders placed with, and goods delivered by, the suppliers interviewed.

Finally, we have much appreciated and benefited from the help, comments, and suggestions of many of our colleagues throughout this study.

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APPENDIX A: THE THEORETICAL CONCEPT

The theoretical concept of the study described here has to fulfil three requirements:

- it has to be adapted to the level of information which industrial managers are willing to provide,
- managers must understand what information is required, and
- the concept must be such that the required information can be provided at all.

The "surplus" concept, as developed by Massé, Ref.[11], turns out to be an appropriate basis for this. The basic ideas of Massé's surplus concept are given below.

Consider an industrial firm which, for convenience, produces only one article. Let V be the number of units of the article it produces in year n. Let F_j be the number of units of the j-th production factor (manpower, machinery, materials, capital, cash resources, etc.) which the firm makes available to produce the V units of the article in year n. Suppose that all produced units are sold. If P is the unit price of the article and P_j is the unit price of factor F_j, the equilibrium equation (output = input) for year n is given by

$$PV = \sum_j P_j F_j \,. \tag{1}$$

Now, consider year n+1. Denote by $F_j + \Delta F_j$ the number of units of the production factors made available in year n+1 and use corresponding notations for the other quantities. For year n+1 the equilibrium equation must then be written as

$$(P+\Delta P)(V+\Delta V) = \sum_j (P_j + \Delta P_j)(F_j + \Delta F_j) \,. \tag{2}$$

We rewrite the equation (2) in the following way:

$$PV + P\Delta V + \Delta P(V+\Delta V) = \sum_j P_j F_j + \sum_j [P_j \Delta F_j + \Delta P_j (F_j + \Delta F_j)] \,. \tag{3}$$

Comparison of equation (1) with equation (3) shows that the first term on the left-hand side and the first term of the right-hand side of equation (3) cancel. Remembering that equation (1) describes the situation of the firm in year n and equation (3) in year n+1, we see that the terms left over in equation (3) describe the change in the factors, the prices and the produced units from one year to the next.

For proper economic interpretation, Massé rewrites equation (3) to obtain

$$P\Delta V - \sum_j P_j \Delta F_j = -\Delta P(V+\Delta V) + \sum_j \Delta P_j (F_j + \Delta F_j) \,. \tag{4}$$

The terms on the right-hand side of equation (4) represent a distribution of resources. The first, $-\Delta P(V+\Delta V)$, goes to the customers as the result of a price change (to their advantage if ΔP is negative), the second, $\Sigma \Delta P_j (F_j + \Delta F_j)$, is the allocation to the different production factors. The left-hand side must give, therefore, the gained resources to be distributed. Massé calls the left-hand side the firm's "gained surplus" and the right-hand side the "distributed surplus".

It is clear that a gained surplus can occur only if something in the firm changes. For instance, the firm may sell more due to better marketing, to better quality, to the introduction of a completely new product, etc. It may also have been able to increase productivity, to obtain better interest conditions on loans, or to improve its situation in other ways. On the other hand, if all the

increased turnover is accounted for by increased production costs, both sides of equation (4) will become zero and there will be no gained surplus.

There must be driving forces which cause these effects to be positive. One of these driving forces might be a contact with a challenging customer such as CERN who asks a firm for new products, requires higher quality, provides a good marketing forum, and so on.

In a given year we may therefore consider a firm in two different situations.

a) The firm has no contact with CERN.
b) The firm has contact with CERN.

Using Massé's concept we can then define a surplus gained by the firm and a corresponding distributed surplus by comparing situation (a) with situation (b) in the same way as we did in equation (4) for the situation of the firm in two different years. If we observe a gained surplus we can say that this surplus was caused by CERN.

It may be very difficult, if not impossible, during the limited time of an interview for an industrial manager to provide information on CERN's influence on each different production factor and its unit price. He may, for example, be able to estimate the hypothetical development of only a few of the production factors. (Of course not all production factors are influenced by CERN. For instance, CERN has practically no influence on the capital cost (interest) of a firm). It was therefore decided to ask industrial managers to quantify only two elements contributing to the gained surplus, namely the sales increase and the cost savings due to CERN. In any case, these are the dominant elements and seem to be the ones which industrial managers can quantify with a reasonable effort. It is therefore necessary to replace the second term of the left-hand side of equation (4) by two terms, so that this becomes

$$P\Delta V - \sum_p P_p \Delta F_p - \sum_c P_c \Delta F_c = -\Delta P(V + \Delta V) + \sum_j \Delta P_j (F_j + \Delta F_j) \,. \tag{5}$$

where, on the left-hand side, the second term represents the change in production costs necessary to achieve the increased turnover, and the third term represents the cost savings due to CERN.

Managers were asked to estimate the first and third terms, but were only occasionally able to provide information concerning the second. In order to express the fact that in this case we are not quantifying all parts of the gained surplus due to CERN, we call the sum of sales increases and cost savings due to CERN the utility U defined by

$$U = P\Delta V - \sum_c P_c \Delta F_c \,. \tag{6}$$

In order to quantify the utility caused by CERN, a mathematical model was developed. This is described in Appendix B.

APPENDIX B: THE QUANTIFICATION FORMULA.

In order to provide a general formula which allows the quantification of the utility due to CERN, we denote the utility arising from increased turnover as U_s and the utility from cost savings as U_c. We then rewrite equation (6) as

$$U = P\Delta V - \sum_c P_c \Delta F_c = U_s + U_c \,. \tag{7}$$

In order to arrive at a simple quantification formula for U_s and U_c, we need a simple model of the mechanism of utility creation.

Taking a simplified view of the mechanisms which determine the success or failure of a firm, we assume that there are certain basic activities, such as launching new products, marketing, research and development, management procedures, manufacturing techniques, quality control, pricing, etc. The efforts devoted to these different activities, which we shall call "Economic Success Activities", bring about the economic results of the firm. Managers usually know the relative effect (not necessarily in money terms) which each activity has on turnover, production costs, etc.

He may say, for instance, that 15% of the firm's turnover M_t is due to their marketing activities. We then call the value 0.15 the marketing success factor for turnover. Such factors, by which we multiply the total turnover to obtain that part of the turnover caused by the corresponding success activities, we call "Economic Success Factors for Turnover". It is clear that the sum of all possible economic success factors for turnover must be 1, since all the success activities together cause the total turnover M_t.

In the same way, we define "Economic Success Factors for Cost Savings", which give the relative effects on cost savings M_c. Once again the sum of these factors must equal 1.

We denote the economic success factors by E_{as} and E_{ac}. The first index a indicates the success activity, while the second indicates sales s or cost savings c.

Using the economic success factors, we can quantify the parts of the total turnover M_t and the cost savings M_c which are due to the corresponding economic success activities. In order to quantify the utilities U_s and U_c due to CERN, managers have to quantify the influence that CERN has had on the different success activities of the firm. Here a manager has to compare the two different situations mentioned in Appendix A: (a) the firm in contact with CERN (real situation), and (b) the firm not in contact with CERN (hypothetical situation). If, for instance, a manager finds that CERN's contribution to launching new products was 30%, and if E_{ns} is the new product success factor for turnover, then the product $0.3 * E_{ns} * M_t$ gives the firm's turnover caused by CERN resulting from new products, and represents a sales utility due to CERN. We call the factor 0.3 the CERN influence factor on the new product success activity for turnover. Such factors, by which we multiply the corresponding economic success factor to obtain CERN's contribution to the corresponding success activity, will be called the "CERN Influence Factors on a Success Activity". Unlike the Economic Success Factors, the sum of which must equal 1, the CERN Influence Factors can take any value between 0 and 1. If all CERN influence factors are zero, CERN has no positive effect on the firm and there is no positive utility. We denote the CERN influence factors by C_{as} and C_{ac}, where the indices are the same as those used for the success factors.

The quantification equations for U_s and U_c therefore become:

$$U_s = (CE)_s * M_t \,, \tag{8}$$

$$U_c = (CE)_c * M_c , \tag{9}$$

with

$$(CE)_s = \sum_a C_{as} * E_{as} , \tag{10}$$

$$(CE)_c = \sum_a C_{ac} * E_{ac} , \tag{11}$$

where the index a on the right-hand side of equations (10) and (11) covers all economic success activities.

Some corrections have still to be made to equations (8) and (9) so that they apply to all cases. In equation (8) we have to take into account the fact that CERN usually influences only part of a firm. To illustrate this, consider a firm making transformers, electric motors and household appliances. Suppose that this firm has made electromagnets for CERN, and that this has subsequently led to improvements in the manufacture of their transformers and motors, but that there was no CERN influence on the household appliance business. The total turnover M_t of the firm in equation (8) must therefore be multiplied by a factor $C_t < 1$, which gives the fraction of total turnover in transformers and motors, influenced by CERN. We call $C_t * M_t$ the "CERN Relevant Turnover" and C_t the "CERN Relevant Factor" of the total turnover. Since the CERN relevant turnover still includes sales to CERN M_s , we have to subtract M_s from the CERN relevant turnover, since direct sales to CERN are not sales increases due to CERN's influence on the firm's economic success activities.

In addition, the resources used to produce the items sold to CERN could have been employed for other customers. We call these sales which would have been made elsewhere "Opportunity Cost" M_o , and this must also be subtracted from the sales utility given by equation (8).

Taking these points into consideration, the sales utility is given by

$$U_s = (CE)_s(C_t * M_t - M_s) - M_o . \tag{12}$$

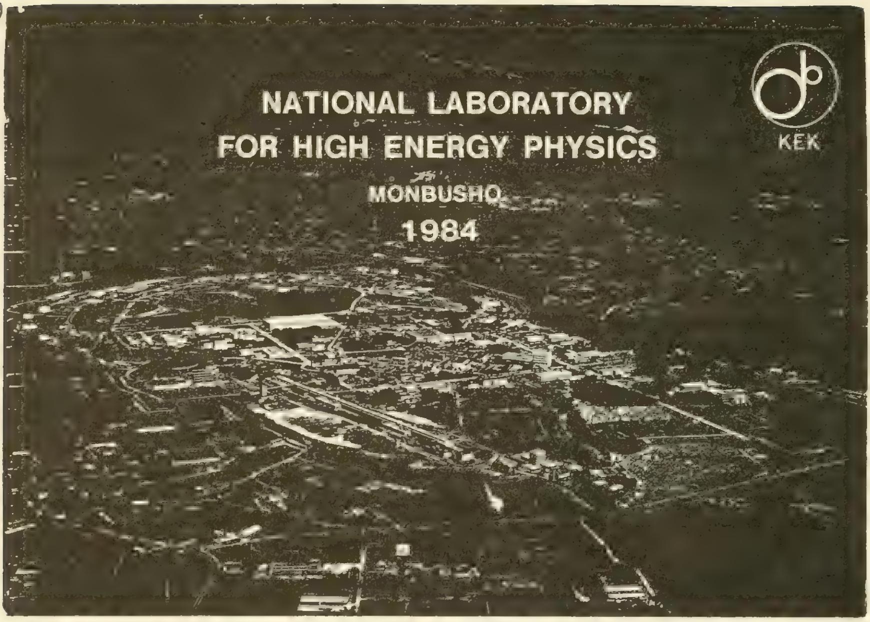
Equation (9) must be expanded to take account of any investment costs M_i which were necessary in order to produce the cost savings, and we obtain

$$U_c = (CE)_c * M_c - M_i . \tag{13}$$

Combining equations (12) and (13) and taking into account any losses M_l which may have occurred due to CERN gives the final quantification equation

$$U = (CE)_s(C_t * M_t - M_s) - M_o + (CE)_c * M_c - M_i - M_l , \tag{14}$$

which, together with equations (10) and (11), is the basis for the quantification of the utility due to CERN. When applying equation (14), we have to take into account the fact that, in principle, all quantities are time-dependent. Therefore, the utility is calculated on a year-by-year basis, and is later expressed in fixed prices referring to a reference year, so that the utilities of different years can be added to give the total utility of a firm.



THE MATTER IN THE NATURE, INCLUDING HUMAN BODY

It is made of atoms which consists of electrons, protons and neutrons. Their sizes are extremely small; an atom is about 1/100 million cm and other three about 1/5trillion cm. What is the force which bounds them together? How do they behave? Nature of the micro-world is not fully understood. Many elementary particles with short life-times, have been discovered. Investigations continue in search of particles yet to be discovered and in understanding the property of the known.

About 150 elementary particles are known today and some of them can be classified according to their characteristics. Physicists are searching for more basic building blocks of the elementary particles.

Elementary Particle				Life Time	Rest Mass
Lepton		Photon	γ	stable	0
		Neutrino	ν	stable	0
		Electron	e	stable	$m_e = 10^{-27}$ gr.
		Muon	μ	5×10^{-6} sec	200 ~ 970 m_e
Meson		π meson	π	$10^{-16} \sim 2 \times 10^{-7}$ sec	
		Kaon	K		
Baryon	Nucleon	Proton	p	stable	1840 m_e
		Neutron	n	900 sec	
	Hyperon	Lambda	Λ	$10^{-14} \sim 3 \times 10^{-8}$ sec	2000 ~ 2600 m_e
		Sigma	Σ		
		Xi	Ξ		
		Omega	Ω		3300 m_e

Method to Investigate the Micro-World

Substance (structure)	Size (cm)	Method (Equipment, Projectile, Energy)
Cells, Bacteria, etc.	≀	Microscope
= Combination of Molecules	1/10thousand	Visible Light
		1~3 eV
	≀	
Molecules = Combination of Atoms		
(Examples)	1/1million	Electron-microscope
Water = H_2O	≀	Electron
Ethyl Alcohol = C_2H_6O	1/50million	10~2000 keV
Atom = Nucleus + Electrons	≀	High Energy
= Combination of Elementary	1/100million	Electron Storage
Particles		Ring
(Example)	≀	Synchrotron light
Hydrogen = $\overbrace{1p + \qquad +}^{\text{Nucleus}}$ 1e	1/1trillion	100~150 keV
Carbon = 6p + 6n + 6e		
Oxygen = 8p + 8n + 8e		Low-Medium
Gold = 79p + 118n + 79e		Energy Accelerator
	≀	Proton, Ion
Elementary Particles =		0.5 MeV~1 GeV
Type? Structure? Property?		
(Elementary Particle Reactions)		
$K + p \to \pi + \Sigma$	1/5trillion	High Energy
$n \to p + e + \nu$		Accelerator
$\pi \to \mu + \nu$		Proton, Electron
(Structure of Elementary Particles)		1~500 GeV
p = 2 u-quark + 1 d-quark	1/10trillion	
π = 1 u-quark + 1 d-quark		

HISTORY

May 1962:	The Science Council of Japan advised the government a construction of large accelerator.
Apr. 1964:	A basic study for the accelerator began.
Aug. 1969:	The Science Council of MONBUSHO (Ministry of Education, Science and Culture) advised the Minister to establish an Institute of Elementary Particles.
Apr. 1971:	National Laboratory for High Energy Physics (KEK) was established as the first Inter-university Research Institute.
Mar. 1976:	Protons accelerated to 8 GeV as designed.
Dec. 1976:	Acceleration to 12 GeV achieved.
May 1977:	High energy physics research at KEK began.
Apr. 1978:	Constructions of the Photon Factory and the Booster Synchrotron Utilization Facility approved.
Jul. 1980:	The collaborative researches using the Booster Synchrotron Utilization Facility began.
Apr. 1981:	The TRISTAN project approved.
Mar. 1982:	The Photon Factory was completed.
Jun. 1983:	The collaborative researches using Synchrotron Radiation began.
Nov. 1983:	Electrons accelerated to 4 GeV at TRISTAN Accumulation Ring.

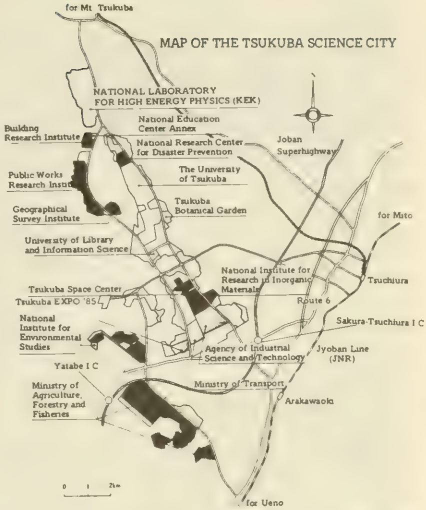
OBJECTIVES OF THE LABORATORY

KEK was established for experimental researches in the elementary particle physics and other related studies. It is an inter-university research institute directly under the MONBUSHO. Its principal accelerators are 12 GeV proton synchrotron, 2.5 GeV electron accelerator and 30 GeV electron-positron collider (TRISTAN). In addition to high energy physics, extensives studies of material and life science are executed with these accelerators.

GOVERNING STRUCTURE OF THE LABORATORY

The Board of Councilors, the Advisory Council for Scientific Policy and Management (PS & TRISTAN) and the Advisory Council for Photon Factory advise the Director General on matters related the administration and scientific programs of the laboratory.

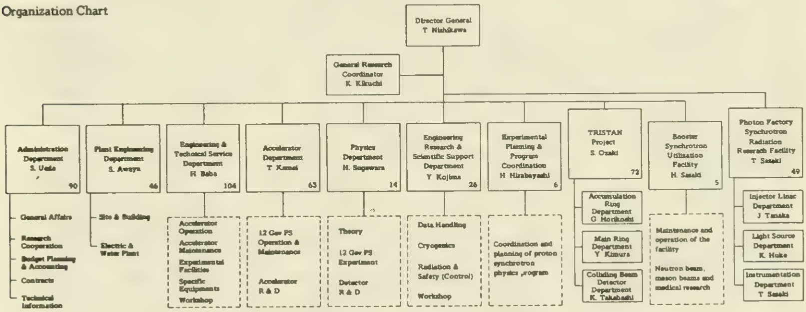
MAP OF THE TSUKUBA SCIENCE CITY



NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS

OHO-MACHI, TSUKUBA-GUN IBARAKI-KEN, 305, JAPAN
TEL 0298-64 1171
TELEX NO 3652-534
CABLE KEK OHO

Organization Chart



Budget

in million yen

	Salaried Wages	Operating Cost	Equipment Cost	Capital Construction		Total
				Large Facility	Technical Comp	
FY1981	1,389	9,181	1,183	2,537	4,052	18,342
FY1982	1,721	9,999	1,145	5,504	4,966	23,335
FY1983	1,989	10,275	168	8,150	9,970	30,552
FY1984	2,199	8,536	105	10,950	8,958	30,748

Staff Members

Director General	1
General Research Coordinator	1
Professors	62
Associate Professors	75
Research Associates	95
Technical & Engineering Staff	148
Administrative Staff	95
Total	477

Site and Buildings (Area)

Site: 2,023,000 m²
Buildings: 99,853 m²

HIGH ENERGY PHYSICS

To examine crystals and molecules, one must use shorter wave length light (X-rays and high energy photon) instead of visible light. To study more basic structure—elementary particles, particles with high energy are needed. Physicists study formation and decay of the particles by colliding high energy particles. The goal of high energy physics is in understanding the structure of the elementary particles, the laws which governs them and, ultimately, the fundamental principle of the nature.

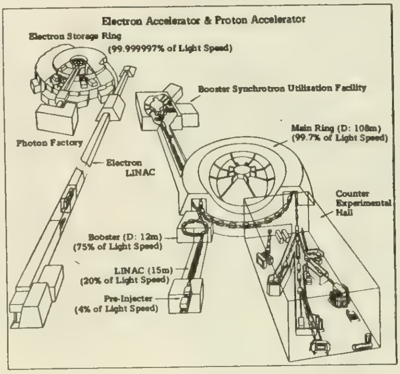
MEANING OF THE HIGH ENERGY RESEARCH

Man has been searching for an answer to the riddle of the nature since Greek era. The quest of "the origin of the matter" was pursued through all the ages. Along with its conceptual development, new technology and research field have been opened. Basic research has contributed to the furtherance of the civilization.

Japan has made many brilliant contributions in the progress of the theoretical physics to date. Now the high energy accelerator in Japan is expected to play an important role in the experimental study of the particle physics and international collaboration in this field.

The effect of having this high energy accelerator extends beyond the study of elementary particles. The accelerator and the technology associated with it will, as seen in the case of the Booster Synchrotron Utilization Facility and the Photon Factory, extend its spinoffs to basic and applied researches in wide ranges of studies in physics, chemistry, biology, engineering and technology, agriculture, etc.

HIGH ENERGY ACCELERATORS AND EXPERIMENTAL APPARATUS used in the high energy physics research are the crystallization of advanced science and technology. Its largeness in scale and refinedness in nature make a heavy demand, and in turn a strong encouragement, on a development of new technology; Thus contributing to the advancement of industrial arts of all kind; Electronics, computer, high vacuum, electric, machinery, and materials, naming a few.



PHOTON FACTORY

Synchrotron Radiation

A high-energy electron traversing a circular orbit under high magnetic field emits an intense radiation. This is called synchrotron radiation, and its spectrum constitutes a smooth continuum extended from radio-waves to X-rays. It is unrivalled light source in extreme ultraviolet and X-rays where lasers are not yet practically available, and it is expected to give a profound effect on many disciplines of science and technology in which the use of short-wave light is of crucial importance.

Electron Accelerator as Synchrotron Radiation Source

The construction of the electron accelerators of the Photon Factory started in 1978 and was completed in March 1982 on the schedule. The accelerator consists of an electron linac and a storage ring. Electrons are accelerated to 2.5 GeV by the electron linac and injected into the storage ring. Electrons emit synchrotron radiation tangentially all along the circular orbit while traversing gaps of bending magnets. Energy lost by emitting radiation is soon recovered from the RF power fed into the resonant cavities. The electron beam accordingly stays within the ultrahigh vacuum path and keeps emitting over a long time.

Research Activities with Synchrotron Radiation

Research programs over a variety of fields in materials science and life science are being carried out by researchers from universities, national laboratories, and private industries. The range of disciplines extends from the fundamental research in physics, in which structures and properties of matter from atoms to protein crystals are studied, to industrial applications such as microanalysis, real time observations of defects in materials, developments of catalysts, lithographic production and studies of VLSI; or medical and physiological applications such as real time observations of structures in living organism like muscles, for instance, and diagnosis of cancers and heart deseases, and many others.

BOOSTER SYNCHROTRON UTILIZATION FACILITY

The booster synchrotron, the injector to 12 GeV PS, accelerates protons to 500 MeV, 20 times per second. Three quarters of 500 MeV protons are supplied to the Booster Synchrotron Utilization Facility. In addition to the researches in neutron physics and solid state study, these protons will be used for diagnosis and treatment of cancer. The facility is opening a new horizon in the research of solid state and nuclear structure, with its high intensity pulsed (50 nsec.) beams.

1) Solid State Research Using Neutrons

The facility for neutron scattering (KENS) opened its operation in June 1980. Here the thermal, epithermal and cold neutrons are produced from metal spallation target. The studies are centered around on the structure of matter in non-equilibrium state, the magnetic momentum of materials, and the structures of organisms and macro-molecules.

2) Atomic Nuclei and Solid State Researches Using Pi-mesons and Muons

Meson Science Laboratory (BOOM—a branch of University of Tokyo) started its operation in July 1980. Pi-mesons from Beryllium, decay in flight through the superconducting solenoid, and become an intense muon beam. The study of solid state by muon spin resonance is internationally acclaimed for its uniqueness.

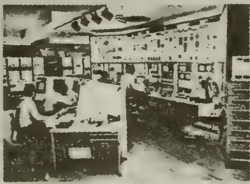
3) Application for Medicine and Biology

Particle Radiation Medical Research Center (a branch of University of Tsukuba) started in 1980. The center is being used for diagnosis and treatment of cancer with protons and neutrons from the facility.

RADIATION AND SAFETY CONTROL
The radiation monitor station in the main control room. The radiation from the accelerator in operation is carefully monitored and controlled.

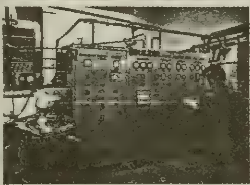
MAIN CONTROL ROOM
The central control station for 12 GeV PS accelerator complex from pre-injector to main ring. A computer system and other electronic devices are used here.

PREINJECTOR (COCKCROFT-WALTON TYPE)
Protons, obtained from gaseous hydrogen, are electrostatically accelerated to 750 keV (4% of the light speed) and are fed to LINAC.

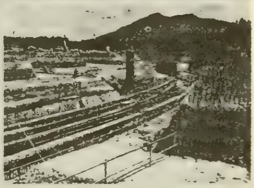


THE CENTRAL COMPUTER
Three HITAC M-200H computers with 40 Mbyte of memory units. With its unique on-line system and KEKOPEN system (an open batch processing system), it provides an essential support to high energy physics experiments.

LOW TEMPERATURE FACILITY
Produces liquid helium and carry out researches in the superconducting phenomena. The photo shows the helium liquefier with a capacity of 120 liter/hour.



WORK SHOP
Modern machining facilities to fabricate special parts for the accelerators and experiments.



USERS FACILITY
Since KEK is the inter-university research center, many scientists from all over Japan and foreign countries come here for their researches. The photo shows a dormitory for visiting scientists.

MEDIUM ENERGY KAON BEAM LINE
Secondary particles produced by accelerated proton beam are led to the experimental set up through a number of magnets and electro-static mass separators. Photo shows the K2 beam channel branching to the left.

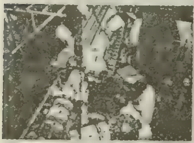
TRISTAN MAIN RING TUNNEL
TRISTAN MR tunnel has a circumference of about 3 km and the floor level is 11.5 m below the ground level. It accommodates 700 electromagnets.

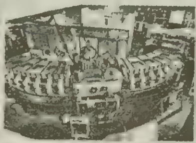
LINAC (LINEAR ACCELERATOR)
Accelerates protons to 20 MeV (20% of the light speed) and sends them to booster synchrotron. It is 16m long and consists of 90 accelerating electrodes.

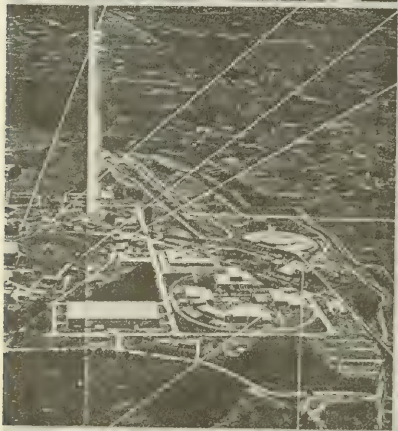
BOOSTER SYNCHROTRON
A rapid cycling proton synchrotron with 12m in ring diameter. Protons are accelerated to 500 MeV (75% of light speed) 20 times per second and a quarter of which are, then, transferred to the main ring

THE MAIN RING
The proton synchrotron with 108m in diameter. There are 48 bending and 56 focussing magnets. Protons circle about 700 thousand times around the ring while being accelerated to 12 GeV (99.7 % of light speed)

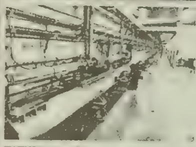
NEUTRON SPECTROMETER–MAX
A wide angle spectrometer in the thermal and epithermal neutron hall of the Booster Synchrotron Utilization Facility for the studies of high energy excitation of materials.





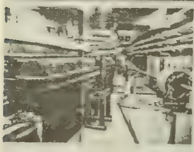


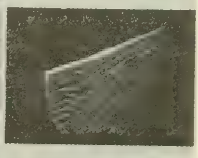
PARTICLE RADIATION MEDICAL SCIENCE CENTER
The center operated by Univ. of Tsukuba performs medical research and cancer therapy using 500 MeV protons from the Booster Synchrotron



ELECTRON LINAC THE INJECTOR OF PHOTON FACTORY AND TRISTAN
The second largest electron linac in the world. Electrons are accelerated up to 2.5 GeV through the accelerator tubes 400 meters long

ELECTRON STORAGE RING, THE LIGHT SOURCE OF PHOTON FACTORY
Nine beam lines for synchrotron radiation from bending magnets, a superconducting wiggler magnet and a permanent magnet undulator are now provided





TRISTAN ACCUMULATION RING
2.5 GeV electrons/positrons from electron linac are accelerated up to 6 GeV in the Accumulation Ring and then injected into the TRISTAN Main Ring. The Accumulation Ring is available for experiments on charm and bottom particles

TRISTAN EXPERIMENTAL HALL "Fuji"
One of the four experimental halls of TRISTAN and will house the VENUS detector. It is a building with two stories above and four under the ground

EXPERIMENTAL HALL OF PHOTON FACTORY
Synchrotron radiation is led by beampipes penetrating through the shielding wall to the experimental hall. Experimental studies using synchrotron radiation from vacuum ultraviolet through X-rays are being carried out at more than 25 stations

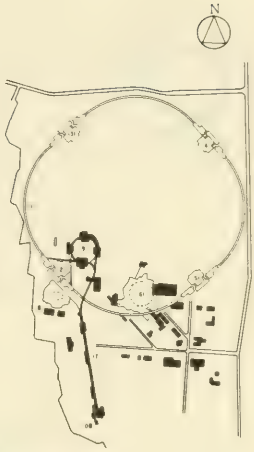
AN EXAMPLE OF SYNCHROTRON RADIATION APPLICATION – X-RAY TOPOGRAPHY
Real time observation of dislocations in a silicon single crystal has become feasible by X ray TV camera without image accumulation.

TRISTAN PROJECT

The TRISTAN (Transposable Ring Intersecting STorage Accelerators in Nippon) complex is under construction in the northern half of the KEK site. The accelerator with 3 kilo-meters in circumferance is for electron-positron colliding experiments.

TRISTAN is designed to accelerate electrons and positrons to 30 GeV, and to make them collide head-on to each other. Contrary to the conventional method of striking stationally target with a projectile, where a major part of the beam energy is consumed in moving the combined mass forward, this new colliding beam method enables us to use entire beam energy for the reaction. With the total energy of 60 GeV, which is released in the pure form of electro-magnetic energy when they collide and annihilate, many new exciting phenomena outlined below can be studied.

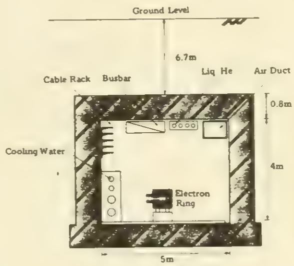
TRISTAN requires many innovations in the technology such as a superconducting magnet, a superconducting radio frequency cavity and the super high vacuum. This accelerator project will bring out a dramatic progress in technology beyond what we have now.



(1) TRISTAN Ring
(2) TRISTAN Experimental Area (Fuji)
(3) TRISTAN Experimental Area (Nikkō)
(4) TRISTAN Experimental Area (Tsukuba)
(5) TRISTAN Experimental Area (Ōho)
(6) 12 GeV Proton Synchrotron
(7) 2 5 GeV LINAC
(8) 2 5 GeV Storage Ring
(9) 6 GeV Electron Accumulation Ring
(10) 200 MeV High Intensity Electron LINAC

PRINCIPAL ACCELERATORS IN THE WORLD

Laboratory	Name	Particle	Energy (GeV)	Year of Completion
Fermi National Accelerator Laboratory (FNAL)	TEVATRON	$\bar{p}p$	1000 × 1000	1986
National Laboratory for High Energy Physics (KEK)	TRISTAN	e^+e^-	30 × 30	1986
The European Organization for Nucl. Research (CERN)	SPS	$\bar{p}p$	270 × 270	1982
	LEP	e^+e^-	50 × 50	[illegible]
Stanford Linear Accelerator Center (SLAC)	PEP	e^+e^-	18 × 18	1980
	SLC	e^+e^-	50 × 50	1987
Deutsches Elektronen-Synchrotron (DESY)	PETRA	e^+e^-	20 × 20	1979
	HERA	$e^{\pm}p$	30 × 800	1989
Institute for High Energy Physics (IHEP), Serpukhov	UNK	$\bar{p}p$	3000 × 3000	—

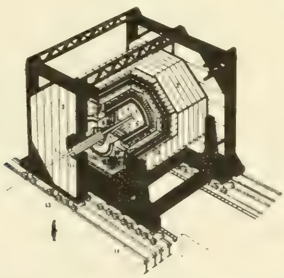


CROSS SECTION OF TRISTAN TUNNEL

WHAT IS EXPECTED IN TRISTAN

1) A search for heavy leptons. Existence of such lepton will infer 7th and 8th flavor of quarks.
2) Studies on the top quark (the 6th quark) and topponium.
3) Experimental study of QCD: "jet" phenomenon (emission of bundles of hadrons), produced by colliding positron and electron, can be studied to understand the strong interaction.
4) Investigation on the internal structure of leptons, which tests the validity of the standard theory.
5) Search for the Higgs particle which may explain the broken symmetry in the elementary particle processes.

1. Beam Pipe
2. Drift Chamber
3. Time Projection Chamber
4. Scintillator
5. Superconducting Solenoid Magnet
6. Lead Glass Cerenkov Counter
7. Gas Shower Counter
8. Extreme-forward Shower Counter
9. Magnet Return Yoke
10. Iron Filter
11. Quadrupole Magnet
12. Support
13. Wheel
14. Guide Rail



THE DETECTORS AT TRISTAN

When an electron and positron collide, they sometimes annihilate and become a pure state of energy. This, in turn, will become a large number of particles flying away from interaction point. The apparatus which detect these particles is very precise, complex and large, sometimes weighing as much as 2500 tons.

OUTLINE OF KEK

May 1984

NATIONAL LABORATORY FOR
HIGH ENERGY PHYSICS
OHO-MACHI, TSUKUBA-GUN
IBARAKI, JAPAN

CONTENTS

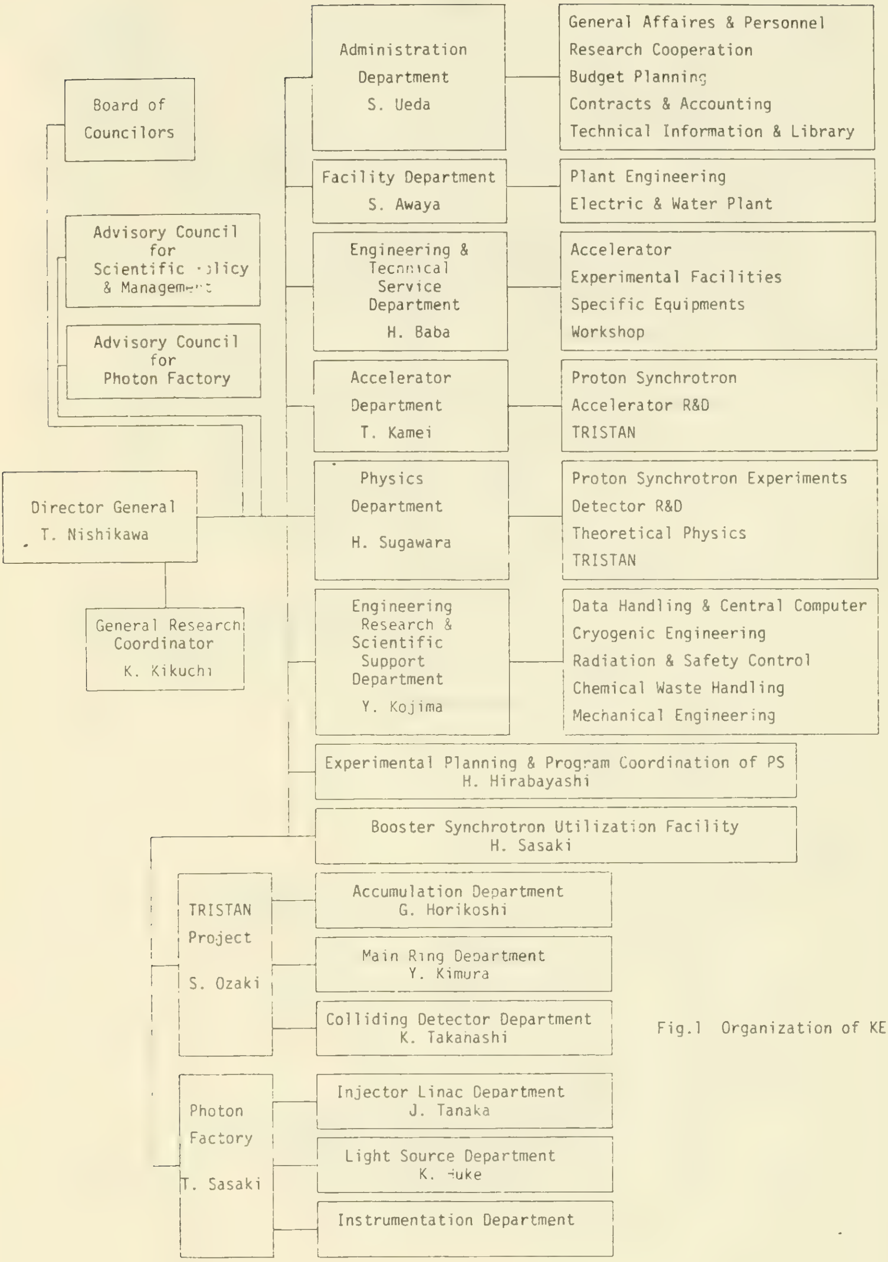


Fig.1 Organization of KEK

1. GENERAL INTRODUCTION

National Laboratory for High Energy Physics (KEK) was established on April 1, 1971, as a national center of high energy physics open to users from universities and other institutions. KEK is the first institute of eleven so called "Inter-University Research Institutes", which is a new type of institute established and supervised by MONBUSHO (Ministry of Education, Science and Culture). KEK is located at the northern boundary of Tsukuba Science City, in which about 40 research laboratories and two universities have been established, and the area of KEK site is 205 ha.

KEK constructed a 12 GeV proton synchrotron as the first major facility, which was completed in 1976 and has been used for physics experiments for these six years. For the construction a capital budget of 13 BY (billion yen) was allocated for five years starting in 1971 and about 300 staff members participated. The proton synchrotron played an important role to raise the level of high energy physics experiments in Japan and eventually has become a milestone to the next step of high energy physics program of KEK, i.e., TRISTAN. The TRISTAN, a 30 GeV electron-positron colliding beam accelerator, was approved by the Government and the ground breaking took place in November 1981. The construction of TRISTAN is well along the schedule and we expect colliding beam experiments in the fall 1986. The TRISTAN e^+e^- collider is open to the international community of high energy physicists and international participation in its experimental program are expected.

Now, with ten years' of history with us, KEK has a new aspect of research activities in addition to research into the fundamental nature of elementary particles. In 1978, two new facilities were established, i.e., the Photon Factory (PF) and the Booster(Synchrotron) Utilization Facility (BUF) in order to cover various fields of experimental studies with the use of high energy accelerators. BUF activities, which makes use of the beam from 500 MeV booster of the proton synchrotron, includes studies on neutron diffraction, pion and muon physics and cancer therapy. The Photon Factory is for research with synchrotron radiations. A complex of 2.5 GeV electron linac and a storage ring was constructed as the second major facility of KEK for four years starting in 1978 with a construction budget of 21 BY.

In FY 1983 the total annual budget of KEK is about 30 BY and the total number of staffs is 480 including 40 part-time secretaries.

In addition to be a national center, KEK is playing an important role in international cooperations. KEK has made two modes of international cooperations: (1) exchange of scientists and (2) cooperative projects with participation of university groups. The most of exchange program of scientists have been executed under the sponsorship of MONBUSHO and JSPS (Japan Society for the Promotion of Science). Making use of these two programs, KEK invited a number of scientists from USA and Western Europe from the very beginning of the history of KEK. They stayed three months or longer at KEK and made joint efforts in construction, physics experiments and R&D work. The number of visiting scientists on these programs is 20 in average every year. Besides them, the number of scientists participating in physics experiments with the support of their own institutions is gradually increasing and now 15 20 foreign scientists stay and work at KEK in this categoly. On the other hand, the number of KEK scientists who participated research activities at foreign laboratories is about 30 every year including short visits for workshops or seminars.

KEK is also a key laboratory for many cooperative programs between university groups in Japan and foreign institutions. Most of them are being executed under a certain formal arrangements or memorandum between both Governments or institutions. In most of these cooperations, KEK is responsible for funding or coodination of these programs.

2. ORGANIZATION

The organization of KEK is shown in Fig.1. It has two covering structures appointed by the Minister of MONBUSHO.

Board of Councilors (Table 1) is an advisory council for the laboratory director and consists of fifteen members, who are presidents of universities, directors of other institutes in this field and eminent scholars. The Board of Councilors to the director with respect to the policy of KEK and also nominates the director of KEK.

Advisory Council for Scientific Policy and Management (Table 2) is for discussing the scientific policy and management of KEK. It consists of twenty-one scientists, who are formally appointed by the Minister of MONBUSHO under the recommendation of the director. Half of the members are scientific staffs of KEK and the other half are elected from the user's group. The Council summarizes and represents opinions of high energy physicists with respect to the scientific program and management of KEK, and also gives recommendations to the director on employment and promotion of scientific staffs of KEK.

Now that research activities at KEK has involved experiments at Photon Factory which are entirely different from high energy physics experiments, Advisory Council for the Photon Factory (Table 3) was established to discuss scientific programs and management of the Photon Factory and Advisory Council for Scientific Policy and Management is responsible for high energy physics programs and the common part of the Laboratory.

Both of these Advisory Councils have their own Program Advisory Committees to examine experimental proposals with respect to their scientific aspects and technical feasibilities.

Table 1 Board of Councilors

(*: Chairman **: Vice-Chairman)

EBASHI, Setsuro	(Professor, Institute for Physiological Sciences)
ESAKI, Leo	(Director, IBM Research Center)
FUKUI, Ken'ichi	(President, Kyoto University of Industrial Arts and Textile Fibers)
KINOSITA, Koreo	(President, Gakushuin University)
**KITAGAKI, Toshio	(Professor, Tohoku University, Physics)
KUBO, Ryogo	(Professor, Keio University, Physics)
MAKI, Ziro	(Director, Research Institute for Fundamental Physics, Kyoto University, Physics)
MIYAKE, Saburo	(Director, Cosmic Ray Laboratory, University of Tokyo, Physics)
*MUKAIBO, Takashi	(Professor Emeritus, University of Tokyo)
NAKAJIMA, Sadao	(Director, The Institute for Solid State Physics, University of Tokyo, Physics)
NISHIJIMA, Kazuhiko	(Professor, University of Tokyo, Physics)
SUWA, Shigeki	(Professor, University of Tsukuba, Physics)
TSUCHIDA, Naoshige	(Director-General, National Museum of Japanese History)
YAMAGUCHI, Yoshio	(Director, Institute for Nuclear Study, University of Tokyo)
YAMAMURA, Yuichi	(President, Osada University, Medical Science)

Table 2 Advisory Council for Scientific Policy and Management

(*: Chairman **: Vice-chairman)

FUJII, Tadao	(University of Tokyo)
HIRABAYASHI, Hiromi	(KEK, Experimental Planning & Program Coordination)
HORIKOSHI, Gen'ichi	(KEK, TRISTAN Project)
ISHIKAWA, Yoshikazu	(Tohoku University)
KAMEI, Tohru	(KEK, Accelerator Department)
KATO, Sadayuki	(INS, University of Tokyo)
KATOH, Kazuaki	(KEK, Eng. Res. and Sci. Support Dep.)
KIMURA, Yoshitaka	(KEK, TRISTAN Project)
KOJIMA, Yuzo	(KEK, Eng. Res. and Sci. Support Dep.)
MASUKAWA, Toshihide	(Research Institute for Fundamental Physics, Kyoto University)
MIYAKE, Kozo	(Kyoto University)
MORI, Shigeki	(University of Tsukuba)
NAGASHIMA, Yorikiyo	(Osaka University)
NAMIKI, Mikio	(Waseda University)
NIU, Kiyoshi	(Nagoya University)
OZAKI, Satoshi	(KEK, TRISTAN Project)
SUGAWARA, Hirotaka	(KEK, Physics Department)
TAKAHASHI, Hidechika	(KEK, Eng. Res. and Sci. Support Dep.)
TAKAHASHI, Kasuke	(KEK, TRISTAN Project)
YAGI, Kohsuke	(University of Tsukuba)
YAMASAKI, Toshimitsu	(University of Tokyo)

Table 3 Advisory Council for Photon Factory

(*: Chairman **: Vice-Chairman)

AKIMOTO, Syun-iti	(Institute for Solid State Physics, University of Tokyo)
ANDO, Masami	(KEK-PF, Instrumentation Department)
ASAMI, Akira	(KEK-PF, Injector Linac Department)
HUKE, Kazuo	(KEK-PF, Light Source Department)
IITAKA, Yoichi	(University of Tokyo)
INOKUCHI, Hiroo	(Institute for Molecular Science)
ISHII, Takehiko	(Institute for Solid State Physics, University of Tokyo)
ITO, Takashi	(University of Tokyo)
KATO, Norio	(Nagoya University)
KIHARA, Motohiro	(KEK-PF, Light Source Department)
KURODA, Haruo	(University of Tokyo)
MITSUI, Toshio	(Osaka University)
NAMIOKA, Takeshi	(Res. Inst. for Sci. Measurements, Tohoku University)
SAGAWA, Takashi	(Tohoku University)
SATO, Isamu	(KEK-PF, Injector Linac Department)
SHIBATA, Shinkichi	(KEK-PF, Light Source Department)
TANAKA, Jiro	(KEK-PF, Injector Linac Department)
TOKONAMI, Masayasu	(University of Tokyo)
YAMAKAWA, Tatsuya	(KEK-PF, Light Source Department)

3. 12 GeV PROTON SYNCHROTRON

The KEK proton synchrotron consists of four stages of accelerators, i.e.

750 KeV Cockcroft-Walton preinjector
20 MeV Linac
500 MeV Fast-cycling Booster
12 GeV Main Synchrotron

as is illustrated in Fig. 2. This scheme was adopted, after many discussions, in order to increase the beam intensity and also to give a possibility of using the booster for various researches such as intermediate nuclear physics or neutron diffraction experiments. The parameters and performance of KEK PS is given in Table 4.

PREINJECTOR

Two sets of 750 kV Cockcroft-Walton high voltage generators are used as preinjectors. One of these was constructed and has been used to accelerate protons. In normal operation, this preinjector injects a 200 mA proton beam to the linac with the pulse duration of 10 ms. The other Cockcroft-Walton generator was recently constructed to accelerate H^- ion beam and a polarized proton beam. For this system a new type of polarized ion source called APOLON was developed.

LINAC

The linac was designed to provide a 100 mA proton beam with 20 MeV. It is a Alvarez type linac with a 15.5 m long single tank operated by 200 MHz RF with a peak power of 3 MW. The maximum catching efficiency for the incident 750 keV beam is 55 % with the use of prebuncher. The maximum intensity achieved is 200 mA, and in the normal operation it produces a beam current of about 140 mA. To install another tank at the downstream of the present tank is being considered to increase the linac energy to 40 MeV and to increase the beam intensity.

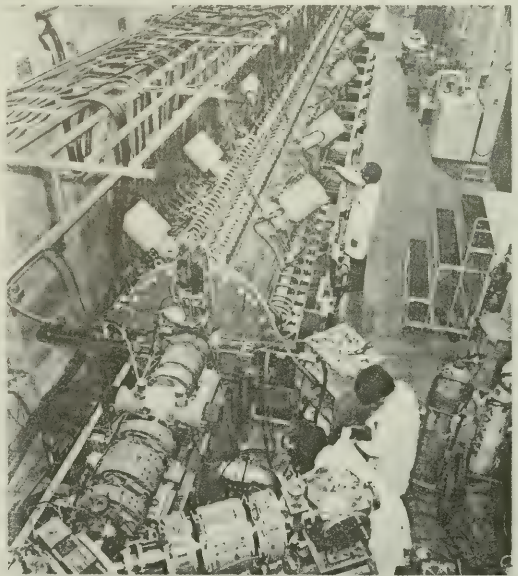
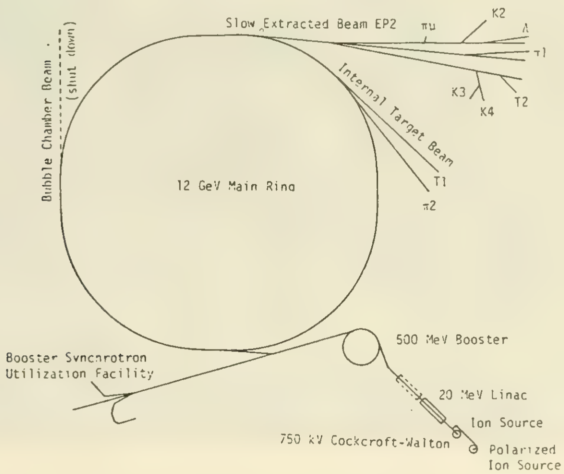


Table 4   Parameters of 12 GeV Proton Synchrotron

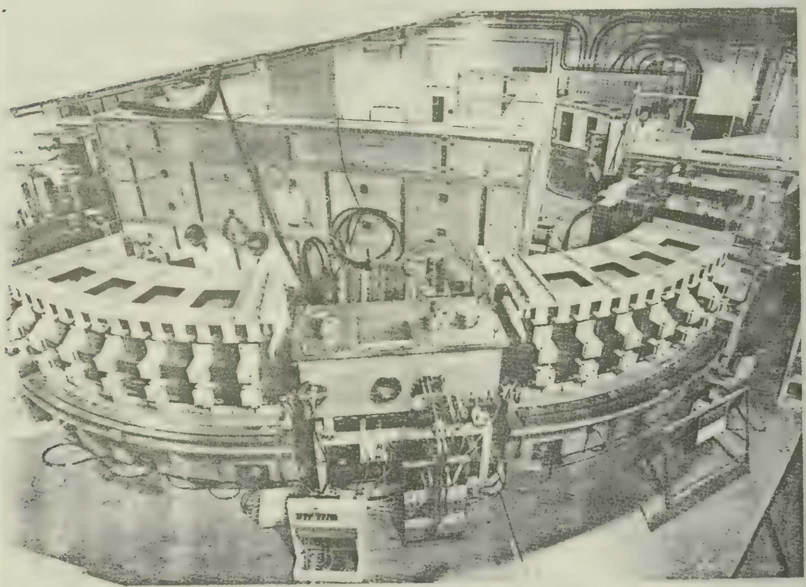
Main Ring	Construction started	April 1971
	First beam obtained	March 1976 (8 GeV) December 1976 (12 GeV)
	Maximum energy	12 GeV
	Injection energy	500 MeV
	Maximum beam intensity	4.4×10^{12} protons per pulse
	Repetition rate	$\sim$ 0.5 Hz
	Ring diameter	108 m
	Injector	20 MeV Linac + 500 MeV Booster
	Focusing type	AG, Separated
	Focusing order	FODO
	Betatron frequency	$\nu_H = 7.1$, $\nu_V = 6.2$
	Bending field	0.15 T (injection), 1.75 (maximum)
	Number of rf cavities	4
	Harmonic number	9
	RF range	6.02 $\sim$ 7.93 MHz
Booster	(Also used for the Booster Synchrotron Utilization Facility)	
	Construction started	April 1971
	First beam obtained	December 1974
	Maximum energy	500 MeV
	Maximum beam intensity	6×10^{11} protons per pulse
	Repetition rate	20 Hz
	Ring diameter	12 m
	Focusing type	AG, Combined
	Focusing order	FDFO
	Betatron frequency	$\nu_H = 2.2$, $\nu_V = 2.3$
	Bending field	0.197 T (injection), 1.1 T (maximum)
Linac	Construction started	April 1971
	First beam obtained	August 1974
	Maximum energy	20 MeV
	Injection energy	750 keV
	Maximum beam current	200 mA
	Ion source	Modified duoplasmatron
	Injector	Open-type Cockcroft-Walton
	Total length	15.5 m
	Number of tanks	1
	Repetition rate	20 Hz
	Rf frequency	201 MHz

Fig.2   Schematic Diagram of KEK 12 GeV Proton Synchrotron



BOOSTER

The booster is a 500 MeV AG (alternate-gradient) synchrotron which consists of eight magnets of combined-function type. The mean radius is 6 m, which is one-nineth of the radius of the main ring, and in one cycle of main ring operation nine pulses from the booster are injected into the main ring. The booster is operated at the repetition rate of 20 Hz. In each cycle, about 6×10^{12} protons (100 mA with pulse width of 10 μs) are injected into the booster by a multi-turn injection. Immediately after each injection, about 6 turns of circulating protons (1.2×10^{12} protons) are observed. Due to the loss of beam during the acceleration, the achieved maximum intensity of the 500 MeV beam is 6.4×10^{11} ppp. With H^- injection into the booster, the intensity is expected to increase by a factor of two or three. An additional RF station was installed in 1977 for the purpose of stable and efficient operation. The extraction of the beam from the booster is performed by the use of a fast kicker (pulse-magnet) and a septum magnet. The main ring is able to accomodate nine pulses of the booster beam in its circumference so that remaining pulses are switched into a beam line leading them to the booster synchrotron utilization facility.



MAIN RING

The separated-function type with a FODO structure was adopted for the main ring. The number of superperiod is four, each period consisting of five normal cells and two cells from which one of the two bending magnets is omitted; one normal cell involves two bending magnets and two quadrupole magnets. Four straight sections are provided for beam injection, fast extraction to the bubble chamber, slow extraction to the counter experimental hall and the RF accelerating station. Nine pulses from the booster are injected into the main ring during the injection period of 0.7 s. The acceleration is performed for the following 0.5 - 0.8 s depending on the maximum energy and 0.5 s flat top is used for high energy physics experiments. The magnetic field is 1.5 KG at the injection and 17.5 KG at 12 GeV. The high magnetic field with a good property was achieved, even in C-type magnet, by the virtue of the oriented low carbon steel.

The designed frequency of betatron oscillations is $\nu_x = \nu_z = 7.25$. However, it turned out after an extensive survey on tune diagram that the best operating point is $\nu_x = 7.10$ and $\nu_z = 6.18$ with correction of the octupole magnets. The maximum beam intensity we have achieved so far is 4.07×10^{12} ppp, and in recent runs the average beam intensity is 3.5×10^{12} ppp. Data on KEK 12 GeV PS are summarized in the following tables and figures. The operation statistics of KEK 12 GeV PS is given in Table 5 and Fig. 3. One should note that the whole accelerator has worked with great reliability and stability so that the accelerator failure is less than 5 %.

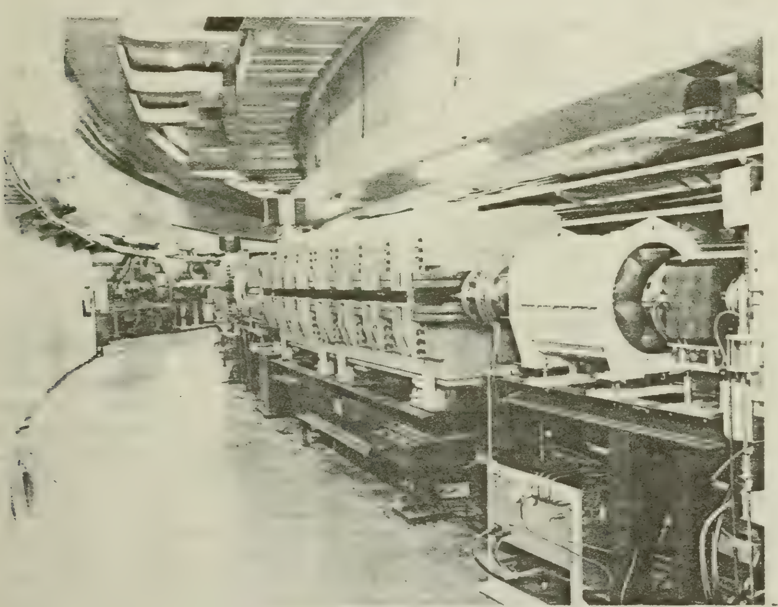


Table 5 Operation Summary of 12 GeV PS in FY 1982

Total operation hour	3652 hrs	
Beam utility	2948	
Slow extraction	2837	
Internal target	2769	
BSUF	3003	
Accelerator study	374	
Accelerator failure	107	
Accelerator tuning	144	
Others	79	
Average beam intensity		
Main Ring	3.5×10^{12}	ppp
Booster	5.5×10^{11}	ppp

Accelerator system down	107.3 hrs	
Injector	36.3	
Preinjector	9.9	(9)
Linac	26.4	(151)
Booster	57.2	
20 MeV transport	12.4	(4)
Magnet	7.1	(19)
RF	3.2	(28)
500 MeV transport	28.5	(18)
BSUF	6.0	(37)
Main Ring	11.8	
Magnet	5.1	(4)
Power supply	1.8	(12)
RF	1.9	(9)
Extraction	1.9	(9)
Controls & Monitor	2.6	(10)
Vacuum	1.3	(15)
Others	0.7	(6)

( ) indicates failure times.

Fig.3 Operation Summary of 12 GeV PS

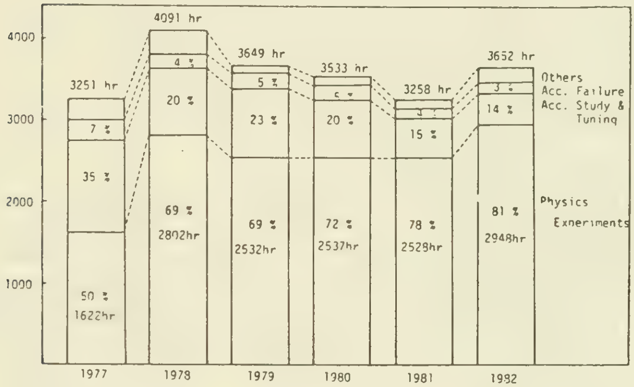
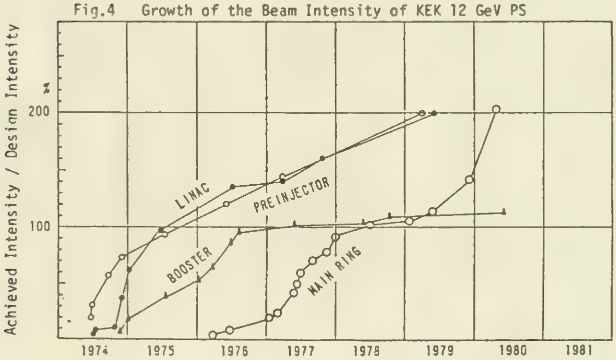


Fig.4 Growth of the Beam Intensity of KEK 12 GeV PS



Design Intensity:

Preinjector	200 mA
Linac	100 mA
Booster	6×10^{11} ppp
Main Ring	2×10^{12} ppp

4. PHYSICS EXPERIMENTS WITH 12 GeV PROTON SYNCHROTRON

Three beam lines have been used for physics experiments as shown in Fig. 2. A fast extracted beam line was provided for the KEK-1m hydrogen bubble chamber, which was shut-down in 1981 after taking about five millions of pictures. Two beams are being used for electronics experiments, i.e., an internal-target beam(π2&T1) and a slow extracted beam EP2. The slow extracted beam is split into several branches for providing direct proton beams, pion beams, enriched kaon beams, anti-proton beams and hyperon beams. Principal characteristics of these beam lines are given in Table 6.

Counter(electronics) experiments with the slow extracted beam have been actively carried out by many inhouse and outside groups since September 1978. An emphasis of the high energy physics experiments has been laid on the study of exotic quark states like baryonium, dibaryon and Z^*. In particular, the polarized proton and deuteron targets with a dilution refrigerating system have been used for the latter purpose. Some experiments, such as rare decay of kaons or direct lepton production, have been made concerning weak or electromagnetic interactions. Another recent experiment of interest is an investigation of monochromatic μ^+, e^+ associated with heavy neutrinos in $K^+ \to \mu^+ + \nu$ and $e^+ + \nu$ decays. In addition the number of experiments using nuclear targets for the study of nuclear physics has been increasing in recent years.

Table 6 Summary of Beam Lines of KEK PS

Beam Line	Momentum (GeV/c)	Particles	Intensity/Pulse
Internal Target Beam			
π2	1 - 4.3	π^+/π^-	$2 \times 10^5/10^5$ at 3 GeV/c
T1	0.5 - 2.3	π^+/π^-	$5 \times 10^4/4 \times 10^4$ at 1GeV/c
Slow Extracted Beam EP2			
K2	1 - 2	K^+/K^-	$5 \times 10^5/10^5$ at 2 GeV/c
		$p/\bar{p}$	$1.7 \times 10^7/1.5 \times 10^4$
		π^+/π^-	$2.2 \times 10^7/1.5 \times 10^7$
K3	0.5 - 1.0	K^+/K^-	$4.2 \times 10^4/10^4$ at 0.55 GeV/c
		$p/\bar{p}$	$7 \times 10^7/3.5 \times 10^2$
		π^+/π^-	$5 \times 10^7/5 \times 10^7$
πμ	0.1 - 1.0	π^-	1.2×10^5 at 0.25 GeV/c
π1	4 - 8	π^+/π^-	$2 \times 10^6/6 \times 10^5$ at 8 GeV/c
T2	1.0 - 6.0	$\pi^\pm$	10^4 at 4 GeV/c
K4	0.4 - 0.8	$\bar{p}$	700 at 600 MeV/c

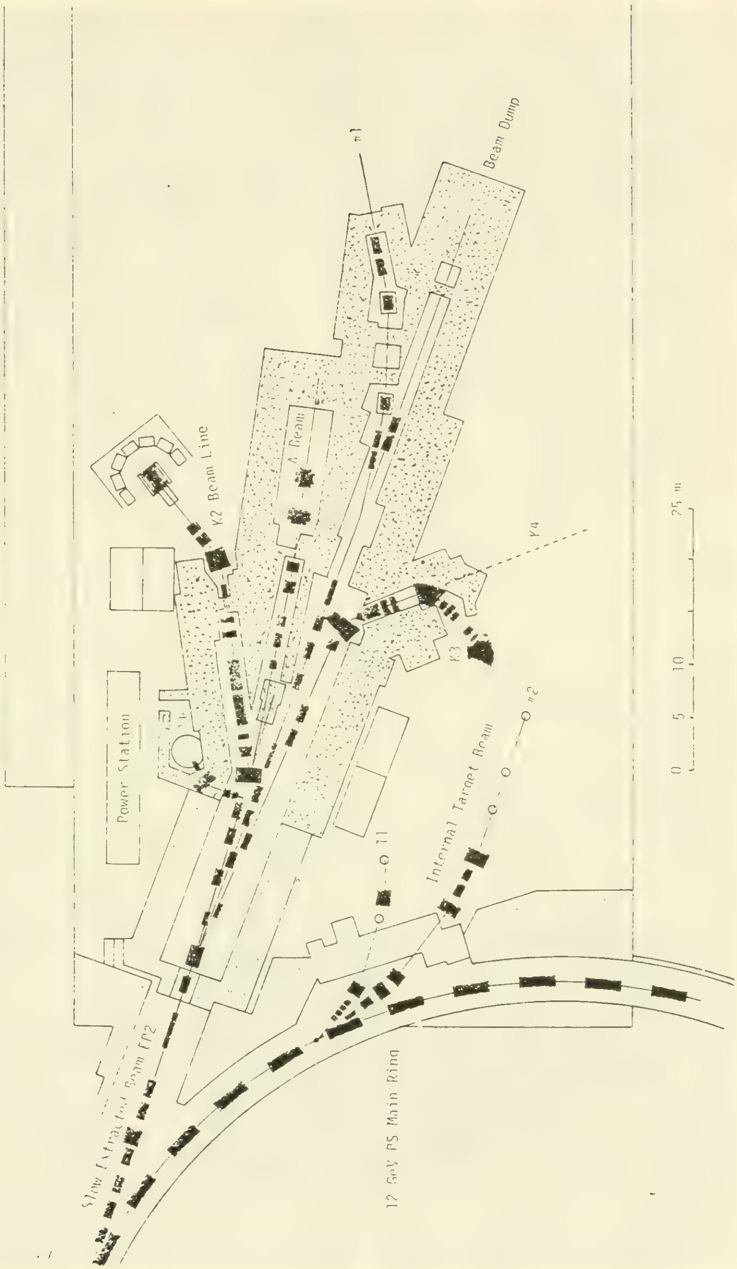
Table 7 List of Approved Experiments

NO.	SPOKESMAN EXPER. GROUP	TITLE	BEAM TECHNIQUE	STATUS
E06	R. Sugawara (KEK-Tokyo-Osaka City-Kinki)	Study of Pion Nucleon Inelastic Scattering in the Intermediate Energy Region	K1 BC	Completion
E10	Y. Nagashima (KEK-Tokyo-Waseda)	Study of Rare Decay $K^+ \to \pi^+ \nu\bar{\nu}$	K3 Counter	Completion
E12	T. Hirose (Tokyo Metro.-Tokyo Univ. A and E)	Study of π-p Three-Body Reactions with Emphasis on Diffraction Dissociation	K1 BC	Completion
E19	K. Miyake (Kyoto-KEK)	Measurements of Differential Cross Sections and Polarizations for $\pi^- p \to \pi^\circ n$ in 1.8 - 3.0 GeV/c	π2 (F1) Counter	Completion
E21	R. Kajikawa (Nagoya-Hiroshima-Osaka-Kyoto-KEK)	Measurements of Differential Cross Sections and Polarizations for $\pi^- p$ elastic scattering at 2 - 4 GeV/c	π2 (F2) Counter	Completion
E23	H. Itoh (Saga-Kyushu-Kyoto)	Disintegrations of Nuclei by Stopping π^-	T1 Counter	Completion
E26	K. Otozai (Osaka-Kyoto-Tokyo Metro.)	Radiochemical Studies of Nuclear Reactions induced by Protons and Pions	T1 Counter	Completion
E33	T. Kamae (Tokyo-Hiroshima)	Measurement of p-$\bar{p}$ total cross sections from 400 to 700 MeV/c Range	K3 Counter	Completion
E34	F. Takasaki (KEK-Saga-Tokyo-Tokyo U of A and E-Kyoto)	Studies of $K^- n\uparrow \to K^+ n$, $K^\circ p$	K2 Counter	Completion
E45	S. Mikamo (KEK-Osaka City-Tokyo-Kyoto-Saitama-Tokyo Metro.)	Direct Lepton Production by Protons	EP2-B Counter	Completion
E49	K. Kondo (Tsukuba-KEK)	Study on Asymmetry in $\Lambda^\circ \to pe\nu$, $p\mu\nu$ decay by using Hyperon Beam	EP2-A Counter	Analysis
E50	T. Kitagaki (Tohoku-Nara-Women-Tohoku-KEK)	Direct Electrons in pp Interactions at 8 GeV/c	K1 BC	Completion
E53	S. Kaneko (Hiroshima)	Studies of π^- Nucleus Interactions at 5 GeV/c in Bubble Chamber	K1 BC	Completion

E57	S. S. Yamamoto (Tokyo)	Studies of p-p Interactions in the Range of 0.8 - 2.0 GeV/c	K1 BC	Analysis
E62	Y. Yoshimura (KEK-Nara-Hiroshima -Tokyo-Osaka City)	Study of Exotic States in $\bar{p}p$ Reactions at 3 - 5 GeV/c	K1 BC	Analysis
E63	K. Miyake (Kyoto-KEK)	Measurements of Differential Cross Sections and Polarizations for $\pi^- p \to \pi^\circ n$ in 3.5 - 4.0 GeV/c	π2 Counter	Analysis
E64	T. Tsuru (KEK-Kyoto-Tokyo)	Study of 2π, 3π state in π-p Charge-exchange Reactions	π1 Counter	Analysis
E65	K. Nakai (Tokyo-Kyoto-Osaka)	Measurements of Neutrons and Gammas from π or μ capture in nuclei	$\pi\mu$ Counter	Analysis
E66	M. Koshiba (Tokyo)	Measurements of π°, η, $\omega(\varphi)$ and Detection of $X^\circ(2820)$ at high p_T	EP2-B Counter	Withdrawn
E67	H. Yoshinaga (Kyushu)	Preliminary study of π^- beam for Medical Applications	$\pi\mu$ Counter	Completion
E68	M. Kobayashi	Detection of γ and π° from $\bar{p}p$ Annihilation at Rest	K3,K4	Running
E71	K. Nakai (Tokyo)	Space-Time Structure and Correlation in Particle Production in Hadron-Nucleus Interaction	$\pi\mu$ π2	Analysis
E72	T. Yamazaki (Tokyo)	Muon Spin Phenomena	$\pi\mu$	Completion
E73	H. Yoshinaga (Kyushu)	Fundamental Investigation on π-meson Therapy	$\pi\mu$	Completion
E74	K. Nakamura (Tokyo)	Baryonium in $\bar{p}p$ Reactions below 1 GeV/c	K3 ($\bar{p}$)	Analysis
E75	K. Ogawa (KEK-Saga-Kyoto -Tokyo)	Measurement of P-parameter in pn Elastic Scattering	K2 (p)	Completion
E79	T. Kitagaki (Tohoku-KEK -Nara Women)	Calibration Experiments of Electro-magnetic Cascade showers by Ta plate in Bubble chamber	K1 (π^-)	Completion
E80	F. Sai (Tokyo)	Dp reactions between 2 to 4 GeV/c	K1 (d)	Analysis
E81	J. Igo A. Masaike (UCLA-KEK-INS Tokyo)	Asymmetry in Elastic Scatterings of $K^\mp$ and $\pi^\mp$ from Deuterium near 1.5 GeV/c	K2	Analysis

E82	S. Mori (Tsukuba)	Nuclear Spallation Reaction with High Energy Particles	K2	Running
E83	Y. Sumi (Hiroshima)	Measurement of Differential Cross Section for $\pi^- d$ in Dibaryon Resonance Region	$\pi 2$	Analysis
E89 E104	T. Yamazaki (Tokyo)	Search for Heavy Neutrinos by $K\mu_2$ Decay	K3	Completion Analysis
E90	K. Nakai (Tokyo)	Space and Time Structure of High Energy Nuclear Reaction	$\pi 2$	Running
E91	R. Chiba (Tokyo Tech.)	Particle Correlation in π-Nucleus Interaction	$\pi\mu$	Analysis
E92	K. Miyake (Kyoto)	Asymmetry Parameter in the $\Sigma^+ \to p\gamma$	K2	Running
E94	H. Itoh (Saga)	Reaction Mechanism of Hadron-Nucleus Interaction	$\pi 2$	Analysis
E97 E107	S. Iwata (Kyoto)	Measurement of Pionic x Rays	$\pi\mu$	Running
E99	T. Hayano (Tokyo)	Search for Right Handed Current in $K\mu_2$ Decay	K3	Completion
T100	Y. Fukushima (KEK)	Test of VENUS Detectors	T2	Running
T101	T. Satoh (KEK)	Test of TOPAZ Detectors	T2	Running
T107	T. Doke (Waseda)	Test of Liquid Ar Detector	T1	Running
E110	R. Yokota (Tokyo Tech.)	Particle Correlation by the π-Nucleus Interaction	$\pi\mu$	Running
E111	R. Chiba (Tokyo Tech.)	Nutron Spectrum from p-1h Reaction	$\pi 2$	Preparation
E113	Y. Miake (Tokyo)	Deuteron from p-Nucleus Reaction	$\pi 2$	Preparation
E114	B. Povh (Max-Planck)	Σ Hypernuclei by (K^-, π) Sectroscopy		Preparation
E119	N. Horikawa (Nagoya-Kyoto)	Spin Correlation Parameter Ann in pn Elastic Scattering		Preparation
E121	T. Inagaki (KEK-Kyoto)	Study of a few Pion States in $\pi^- p$ charge Exchange Reaction	$\pi 1$	Running

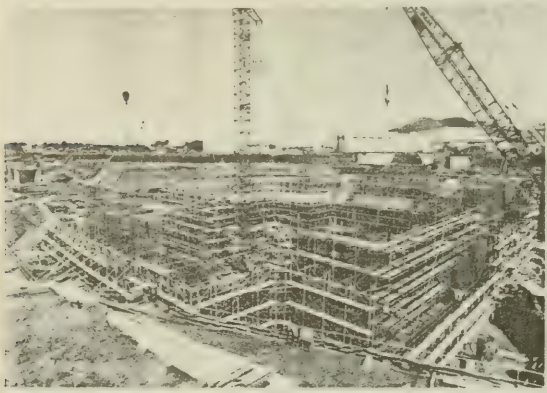
Fig.5 Layout of Counter Experimental Hall (12 GeV PS)



5. TRISTAN

The TRISTAN project was proposed in 1973 as the future plan of KEK. Originally, the nickname "TRISTAN" came from "Tri-Ring Intersecting STorage Accelerators in Nippon" which aimed at super high-energy colliding beam experiments of various types such as pp, $e^{\pm}p$, $e^{+}e^{-}$ and $\bar{p}p$ by choosing a set of intersecting storage rings. The original plan was composed of three rings installed in the same tunnel; two of them being superconducting and the remaining one being conventional. The circumference of these rings was assumed to be six times that of the main ring of 12 GeV PS. The 12 GeV protons were to be accelerated up to 50 GeV by the conventional ring before being injected into the superconducting rings. The two superconducting intersecting rings were to be used for experiments of pp collisions with the maximum center-of-mass energy of about 350 GeV. In addition one could carry out electron-proton and electron-positron colliding beam experiments by a set of conventional and superconducting rings. Among these various possibilities, the first priority of the original TRISTAN plan was put on ep collisions during 1970's.

More recently, however, the TRISTAN plan was extended to higher energies for it is ascertained that achieving a momentum transfer larger than 100GeV/c was highly desired to investigate strong and weak interactions. The new version of the TRISTAN was designed so as to have the possible largest ring that the KEK site could accomodate. This makes it possible to accelerate electrons up to 25 $\sim$ 30 GeV and protons to more than 300 GeV. At the same time, the entire TRISTAN plan has been divided into phases. In Phase I, a conventional ring will be constructed with the accelerator enclosure which can accomodate the future extended plans. This conventional ring enables us to perform electron-positron colliding beam experiments at the center-of-mass energies of 50 $\sim$ 60 GeV which is able to challenge a number of interesting topics of elementary particle physics. The TRISTAN Phase I project was approved by the Japanese Government as a five-years program starting in 1981 and the ground breaking ceremony was held on November 19, 1981. Taking account of the fact that the TRISTAN Phase II has not been fixed, the origin of the nickname of TRISTAN was modified to "Transposable Ring -----" as the more flexible plans could come into consideration.



Construction of the TRISTAN experimental hall " Fuji ", named because this hall is located in the direction of Mount Fuji when viewed from the center of the ring This hall will house the VENUS detector

ELECTRON-POSITRON COLLIDING ACCELERATOR

The TRISTAN Phase I (e^+e^- colliding accelerator) consists of three accelerator units:

2.5 GeV	Electron (Positron) Linac
6 ∿ 8 GeV	Accumulation Ring (AR)
30 GeV	Main Ring (MR)

The 2.5 GeV electron linac, which was primarily constructed for the Photon Factory, is used as the injector to the Accumulation Ring. Positrons are produced by a new 200 MeV electron linac and accelerated up to 200 MeV by another linac before being injected into the 2.5 GeV linac. The Accumulation Ring stores positrons and electrons and accelerates them up to 8 GeV. This ring is also used to perform e^+e^- colliding beam experiments at about 2 × 6 GeV. The large Main Ring has a fourfold symmetry with four long straight sections which is used to perform colliding beam experiments and to install long RF cavity systems needed to compensate radiation loss of circulating particles. Two of four experimental halls, i.e., North-East(Tsukuba) and South-West(Fuji) halls, will have an extra length in the beam direction so as to accomodate ep colliding beams in the future plan. The parameters of AR and MR are summarized in Tables 8a and 8b. The total budget of construction of TRISTAN e^+e^- complex is estimated to be about 85 BY(Accelerator, 37 BY; Experimental Facility for two detectors, VENUS and TOPAZ, 10BY; Building 38 BY).

Fig.6 Layout of TRISTAN

1. 12 GeV Proton Synchrotron
2. TRISTAN Main Ring
3. Experimental Areas
   - Fuji (South-West)
   - Tsukuba (North-East)
   - Nikko (North-West)
   - Oho (South-East)
4. 2.5 GeV Electron/Positron Linac
5. Electron Storage Ring for Photon Factory
6. TRISTAN Accumulation Ring
7. Electron Linac for Positron Generation

Table 8a Basic Parameters of the TRISTAN Phase I

	Main Ring	Accumulation Ring
Circumference	3018.1 m	377.0 m
Average Radius of Curved Section	346.7 m	47.7 m
Long Straight Sections	4 x 194.4 m	2 x (19.5 m + 19.1 m)
Total Length of RF Sections	509.4 m	38.1 m
RF Frequency	508.6 MHz	508.6 MHz
Injection Energy	6 - 8 GeV	2.5 - 3 GeV
Maximum Energy	25 - 30 GeV	6 - 8 GeV
Number of Interaction Regions	4	2
Maximum Design Luminosity	$8 \times 10^{31}\ cm^{-2} \cdot s^{-1}$	$2 \times 10^{31}\ cm^{-2} \cdot s^{-1}$

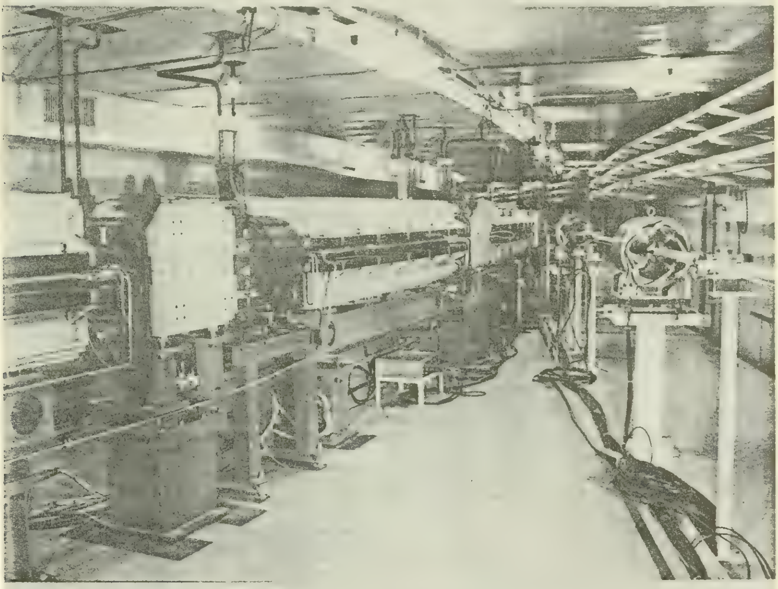
Table 8b Design Parameters of the TRISTAN Phase I

<u>Main Ring</u>	
Average Machine Radius	480.34 m
Bending Radius	246.53 m
Normal Cells	116 x 16.12 m
Dispersion Suppressing Cells	20 x 15.42 m
RF Cells	40 x 14.15 m
Experimental Insertions	4 x 6 m
Number of Bending Magnets	272
Number of Cell Quadrupoles	344
Number of Insertion Quadrupoles	48
Revolution Frequency	99.33 KHz
RF Frequency	508.58 MHz
Total Length of RF Cavities	320 m
Total Length of Higher Mode Cavities	65 m
Beam Energy	30 GeV
Bending Field	0.406 T
Strength of Cell Quadrupoles	16.1 T/m
Betatron Tune (ν_x/ν_y)	37.15/39.10
Momentum Compaction Factor	1.493×10^{-3}
Radiation Loss per Turn	290 MeV
Natural Energy Spread (σ_E/E)	1.639×10^{-3}
Natural Horizontal Emittance	1.785×10^{-7} m·r
RF Peak Voltage	382 MV
Synchrotron Oscillation Frequency	9.95 KHz
Natural Bunch Length (σ_z)	1.17 cm
Betatron Function at Colliding Point (β_x^*/β_y^*)	1.12 m/0.07 m
Beam Size at Colliding Point (σ_x^*/σ_y^*)	0.434 mm/0.027 mm
<u>Accumulation Ring</u>	
Average Machine Radius	60.0 m
Bending Radius	23.17 m
Normal Cells in Arc	28 x 8.8 m
Number of Bending Magnets	56
Number of Quadrupoles	86
Revolution Frequency	0.795 MHz
RF Frequency	508.58 MHz
Total Length of RF Cavities	29.6 m
Beam Energy	6 GeV
Bending Field	0.86 T
Betatron Tune in Arc (ν_x'/ν_y')	7/7
Momentum Compaction Factor	0.013
Radiation Loss per Turn	4.9 MeV
Natural Energy Spread (σ_E/E)	1.1×10^{-3}
Natural Horizontal Emittance	2.7×10^{-7} m·r

ELECTRON-POSITORN COLLIDING BEAM EXPERIMENTS

The TRISTAN Phase I-e^+e^- colliding beam accelerator-aims at search for new particles such as toponiums, Higgs bosons, heavy leptons and free quarks and to study electroweak interactions, quartum chromo-dynamics, etc, in the new energy domain beyond that reached by PEP(SLAC) and PETRA(DESY). The discovery of topnium, the bound state of t quark and its antiparticle, is one of the most exciting of these topics. If the mass of the toponium is about 50 GeV, one can expects 500 toponium events produced per week with an average luminosity of $5 \times 10^{30} cm^{-2} sec^{-1}$ that we anticipate to achieve. Following the determination of the mass, spectroscopic study in decay of the toponium is also of great interest, including a decay into the Higgs scalar or strong-and weak decays which will give valubale data for QCD.

To date three proposals for TRISTAN experiments have been approved; the TOPAZ the VENUS and the AMY collaborations. The both of TOPAZ and VENUS detectors are general purpose detectors and are similar in basic configuration. They will be installed in the Fuji and Tsukuba areas respectively. The third experiment, the AMY project has been approved recently. This compact detector will be built by a joint US/Japnese team for installation in the Oho(Suth-East) hall. Basic componnents of these detectors are shown in Table 9.



TRISTAN Accumulation Ring with the positron injection line on the right. Accumulation Ring accelerated electrons to 4.2 GeV on 18 November 1983, just two years after the groundbreaking ceremony on 19 November 1981.

Table 9 Outline of the TOPAZ, VENUS and AMY Detectors

Component	TOPAZ	VENUS	AMY
Inner Chamber	Cylindrical Drift Chamber (Cathode Strip Readout)	Cylindrical PWC (Cathode Pad Readout)	None
Central Tracking Chamber	TPC with dE/dx (4 atm) ID = 70 cm OD = 250 cm (~ 12000 Readout Channels)	Cylindrical Drift Chamber ID = 50 cm OD = 252 cm (~ 7000 Readout Channels)	Cylindrical Drift Chamber ID = 30 cm OD = 135 cm (~ 11520 Readout Channels)
Time-of-flight	64 elements (13 cm x 4.5 cm)	96 elements (10.5 cm x 5 cm)	None
Magnet Coil	Superconducting Solenoid B = 1.2 T	Superconducting Solenoid B = 0.5 T	Superconducting Solenoid B = 3.0 T
Magnetic Field Volume	2.72 mϕ x 5.08 m	3.4 mϕ x 5.8 m	2.22 mϕ x 2.2 m
Barrel Drift Chamber	Conductive Plastic Tube (Cathode Strip Readout)	Limited Streamer Tube (Charge Division Readout)	None
Barrel Electromagnetic calorimeter	Lead Glass, Cylindrical Array 4320 Units (120 X_0 Long) Coverage 35° - 145°	Lead Glass, Radial Array 5280 Units (20 X_0 Long) Coverage 37° - 143°	Lead Sheet-conductive Plastic Sampling Calorimeter (9846 Readout Channels) (15 X_0 Long) Coverage 37° - 143°
Muon Detectors	3 Iron Slab Layers 8 Drift Chamber Layers	2 Iron Slab Layers Limited Streamer Tubes	1.3 m Return Yoke Iron One X-Y Coordinate Measurement by Drift Tubes
End Cap Drift Chamber	Conductive Plastic Tubes (Cathode Strip Readout)	Limited Streamer Drift Tubes (Cathode Readout for Trigger)	None
End Cap Electromagnetic calorimeter	Lead Plates PWC Tube Layers	Liquid Argon Shower Detector (4000 Readout Channels)	None
Luminosity Monitor	Lead-scintillator	PWC and Lead-scintillator	Drift Tubes and Lead
Collaborating Group	LBL, Univ. of Calif. Nagoya Univ. Nara Women's Univ. Nat'l Lab. for High Energy Phys. (KEK) Osaka City Univ. Tokyo Univ. of Agric. & Tech. Inst. for Nucl. Study, Univ.of Tokyo Univ. of Tokyo	Fukui Univ. Hiroshima Univ. KEK Kobe Univ. Kyoto Univ. Osaka Univ. Rikkyo Univ. Tokyo Univ. of Agric. & Tech. Tohoku Gakuin Univ. Tohoku Univ. Tokyo Metropolitan Univ. The Univ. of Tsukuba Wakayama Med. College	KEK Korea Univ. Niigata Univ. Ohio State Univ. Saga Univ. Saitama Univ. Tokyo Inst. of Tech. Univ. of Rochester Virginia Polytechnic Inst.

6. BOOSTER SYNCHROTRON UTILIZATION FACILITY

The Booster Synchrotron Utilization Facility(BSUF) was founded in 1977 to make use of 500 MeV protons extracted from the booster of the 12 GeV PS. Under the current operation condition of the proton synchrotron about a quarter of 500 MeV booster beam is injected into the 12 GeV main ring so that the remaining three quarters of the booster beam is used in BSUF. Since the booster produces 20 pulses of about 6×10^{11} protons per second, the proton intensity available for BSUF is 9×10^{12} protons/s. BUSF consists of three experimental areas : the neutron experiment area(KENS), the pion and muon experiment area(BOOM), and the medical research area. The neutron project has been mainly promoted by Tohoku University group that designed and constructed a pulsed spallation neutron source and cold neutron channels, which was completed in 1979, and experiments started in 1980. The pion and muon facility is affiliated with the Meson Science Laboratory, the University of Tokyo. The muon channel including a long superconducting solenoid worked successfully in June 1980 and the muon yield was found to be 10^5 muons/pulse. The medical research area for cancer diagnosis and therapy is affiliated with Particle Radiation Medical Science Center(PARMS), the University of Tsukuba, and started its activity at the beginning of FY 1982.

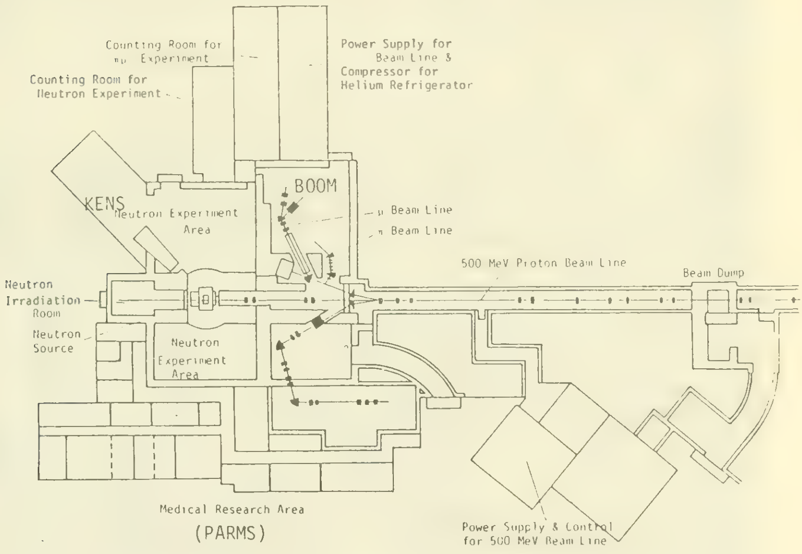
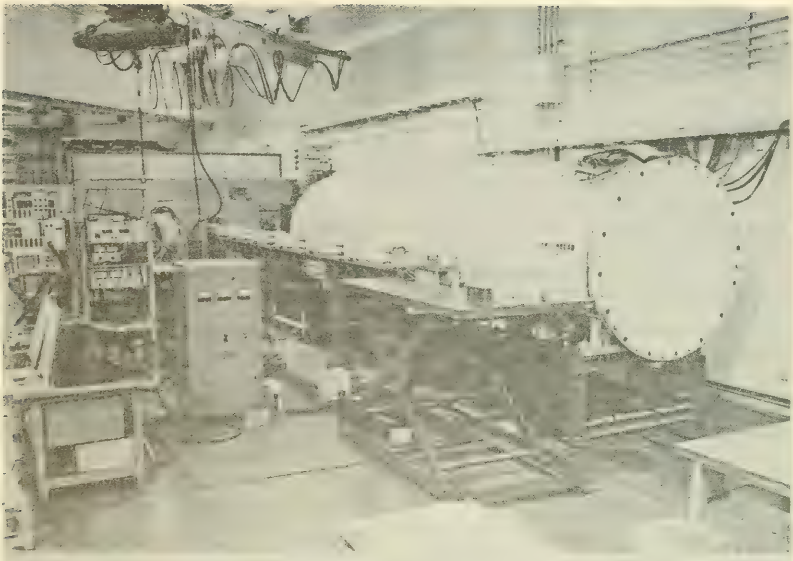
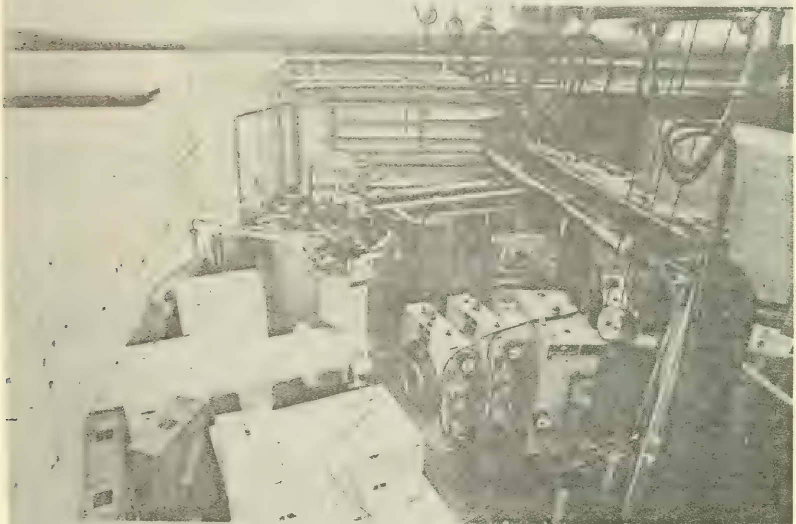


Fig.7 Layout of Booster Synchrotron Utilization Facility (BSUF)



Cold neutron channels installed in the neutron experimental area

Muon channel with a superconducting solenoid



7. PHOTON FACTORY

The Photon Factory is a national synchrotron radiation research facility affiliated with KEK. Originally this project was planned to establish an independent institution, however, after a heated discussion, it was finally established as a part of KEK. The construction of the Photon Factory was approved as a four years program starting in 1978. The accelerator consists of a 2.5 GeV electron linac and an electron storage ring and is able to yield a number of intense pencil beams of photons in a wide range of wavelength, which can be used for studies in physics, chemistry, biology, medical science, pharmacology, geology, lithography, etc.

The ground breaking ceremony was held on January 25, 1979. The first 2.5 GeV beam was obtained in early February, 1982, and the first turn in the storage ring was observed on February 18 and the beam accumulation reached to 6 mA on March 11.

Thus the constuction was completed in FY 1982 on schedule at a total cost of about 18.5 BY, in which 10 BY is for the accelerator and experimental facilities, and 8.5 BY for buildings, the electric power station and the water cooling plant.

The Photon Factory is open for users from universities and other institutions such as research institutes under other Ministry of the Government. Applications from private companies are also admitted for appropriate objects of research.

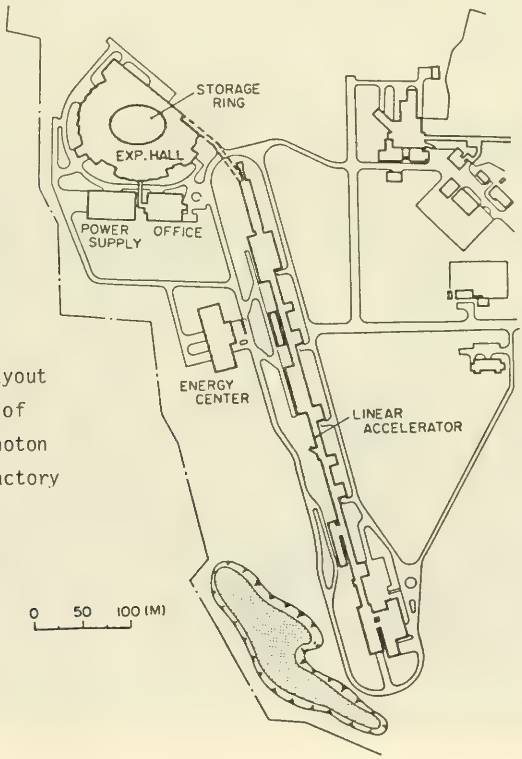
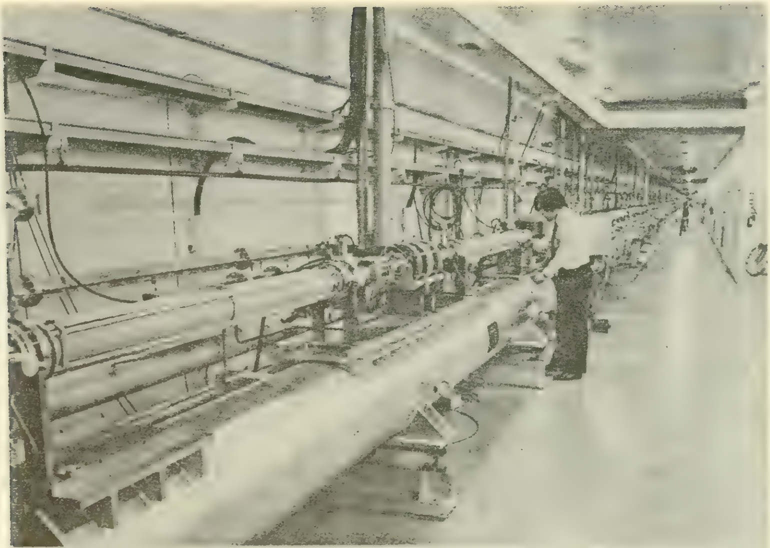


Fig.8 Layout of Photon Factory



2.5 GeV electron linac of Photon Factory. The photo shows 400 m long accelerating tube. This linac is used as the injector of TRISTAN.

2.5 GeV electron storage ring of Photon Factory. The photo shows the injection section

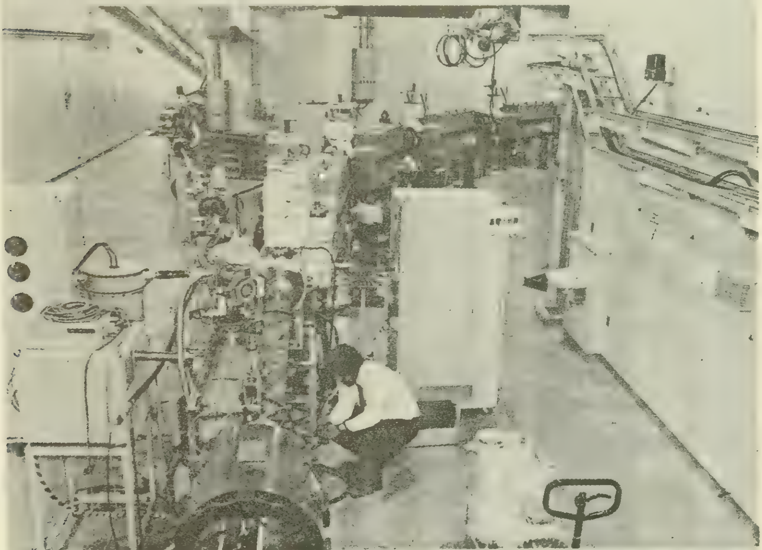


Table 10 General Parameters and Operation Statistics of PF Accelerator

Electron Linac

Energy	2.5 GeV
Peak Current	50 mA
Beam Pulse Width	> 1 μs
Repetition Rate	50 pps
Energy Spead	< 0.5 %
Normalized Emittance	< 10 cm·mr
Total Number of Accelerator Guide	160
Length of Accelerator Guide	1.9 m
Frequency	2856 MHz
Length of Acceleration Unit (Composed of 4 Acceleration Guides)	9.6 m
Total Number of Acceleration Unit	40
Number of Klystrons	41
Peak Power per Klystron	30 MW
RF Pulse Width	3 μs
Injection Energy	30 MeV
Type of Gun	Triode
Gun Voltage	– 100 KV
Gun Pulse Width	2 ns ∿ 2 μs

Storage Ring

Energy	2.5 GeV (Maximum 3 GeV)
Mean Radius	29.77 m
Radius of Curvature	8.66 m
Number of Long Straight Sections	2
Number of Medium Straight Sections	8
Focusing Order in Normal Cell	FODO
Field Strength of the Bending Magnet	9.6 KG (Maximum 12 KG)
Aperture	70 x 12 mm^2
Number of Quadrupole Magnets	58
Total Magnet Power	1.0 MW (for 2.5 GeV)
RF Frequency	500.0 MHz
Harmonic Number	312
Synchrotron Radiation Loss	399 KeV/rev (without Wiggler)
Radiated Power	265 KW (without Wiggler)
RF Voltage	2.1 MV
Synchronous Phase	79°
Number of Cavities	4
Average Pressure	10^{-9} Torr
Lifetime	10 hr
Injection Energy	2.5 GeV
Energy Width of Linac	0.2 %
Emittance of Injected Beam	0.02 π mm mrad
Injection Rate	1 - 10 Hz
Injection time	10 min

Beam Time Statistics

Run	Period	Total Time (hours)	Users' Time (hours)	Machine Failure (hours)	Average Current (mA)
2	6/2 ∿ 7/17/82	407	185	23	39
3	10/21 ∿ 12/10/82	274	121	13	53
4	1/13 ∿ 3/5/83	617	356	34	75
5	6/7 ∿ 7/23/83	484	333	6	86

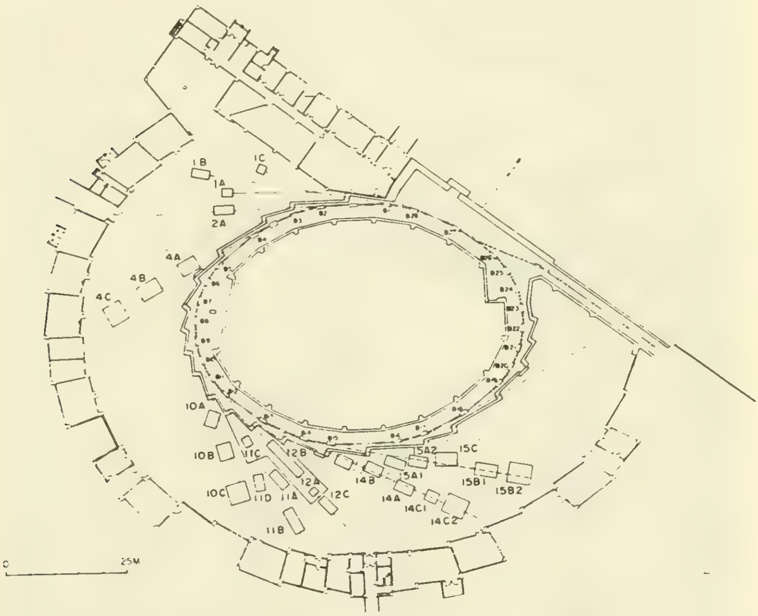
As can be seen in Fig 8, nine main beam lines have been constructed till the end of September, 1983. They are as follows:

X-ray lines	BL-4, 10, 15
VUV lines	BL-11, 12
Hard X-ray wiggler line	BL-14
Soft X-ray undulator line	BL-2
Lithography line	BL-1
Monitor line	BL-21

The lithography line was constructed by Nippon Telegraph and Telephone Public Cooperation.

The number of experimental stations presently available for users is 25. The design and construction of experimental instruments and apparatuses was started in parallel with beam line design. However the total number of in-house staffs is short of constructing all of these varions equipments so that a number of working groups were voluntarily formed among potential users to participate in the construciton of experimental stations. Experiments started in June, 1982, and about 100 experiments have been executed till the end of FY 1983.

Fig.9 Layout of Experimental Hall (Photon Factory)



8. THE US/JAPAN COOPERATION ON HIGH ENERGY PHYSICS

The US/JAPAN cooperation on high energy has been executed under the Implementing Arrangement between the U.S. Department of Energy and the MONBUSHO(Ministry of Education, Science and Culture) of Japan on Cooperation in the Field of High Energy Physics, which falls under Agreement in Research and Development in Energy and Related Fields signed on May 2, 1979. The US/JAPAN Committee on High Energy Physics, consisting of six members from each side, was formed after the signing ceremony of the Implementing Arrangement at SLAC on November 11, 1979, and has been held once a year in the U.S. and Japan alternately to coordinate and moniter cooperative programs. Dr. J. Leiss, DOE, and Dr. T. Nishikawa, KEK, have been co-chairmen for the five Committee meetings for 1979-1983:

1st meeting	Nov. 12, 1979, at SLAC
2nd meeting	May 19-20, 1980, at KEK
3rd meeting	May 26-27, 1981, at FNAL
4th meeting	May 24-25, 1982, at Fuji
5th meeting	May 24-25, 1983, at BNL

For the first five year period of cooperation, thirteen projects, Table 11, have been executed according to the guideline for the allocation of budget:

(a) 60% for physics experiments at US facilities which are complimentary to KEK
(b) 20% for kind of physics experiments similar to KEK program
(c) 10% for research and development of accelerator technology
(d) 10% for research and development of detector technology

The total amount of Japanese funding to this program for 1979-1983 is about 6.4 BY and about 90 Japanese scientists have participated in cooperative activities at U.S. laboratories. The collaboration under the Implementing Arrangement has been so successful and of high quality that it has already contributed significantly to progress in high energy physics. As a result of this excellent cooperation, already more than hundred papers and presentations have been published including notable results on charm decays, neutrino interactions and hadron spectroscopy. In this period, the UCLA group made experiments with KEK 12 GeV proton synchrotron. Now that the TRISTAN project is under way at KEK, participation of U.S. groups in the TRISTAN experiments is being realized. The US/JAPAN Committee on High Energy Physics discussed the cooperative programs in the second five year period, and approved the following four general programs, including the last two of which are new initiatives:

Program A	Joint use of existing and new high energy physics accelerator facilities in the U.S. and Japan
Program B	Joint program of high energy accelerator and detector instumentation research and development
Program C	Joint participation in design studies leading to the possible construction and subsequent use of new forefrout facilities for high energy physics
Program D	Collaborative studies of paiticle physics which do not depend on beam generated by accelerators

Table 11 Summary of Cooperative Projects

(a) Physics Experiments at US Facilities which are complementary to KEK.

1. BNL: Neutrino	Measurement of elastic scattering of neutrinos from electrons and protons (E734) and short wavelength neutrino oscillation (E775).
2. FNAL: CDF	Proton-antiproton colliding experiment (CDF).
3. FNAL: E605	Lepton and hadron pair production near kinematical limit (E605).
4. FNAL: Emulsion	Study of weak decay lifetimes of neutrino induced particles in a tagged emulsion spectrometer (E531) and measuring charm- and B decays via hadronic production in a tagged emulsion spectrometer (E653).
5. FNAL: Bubble Chamber	Bubble chamber experiments in 200-1000 GeV energy region (E565/570 & E636).
6. SLAC: Bubble Chamber	Photoproduction of charm partcles in the SLAC hybrid facility (BC72/73 & BC75).

(b) Kind of Physics similar to KEK Program.

7. LBL: SLAC-PEP 4 (TPC)	Participation in the electron-positron colliding experiment (PEP-4) at SLAC-PEP and development of new detection and data handling technology.
8. SLAC: LASS	Multi-particle production experiment with LASS facility (E132/135).

(c) Research and Development of Accelerator Technology.

9. BNL/FNAL: SC Magnet	Development of superconducting magnet.
10. SLAC: SC RF Cavity	Research and development on superconducting rf cavity.
11. SLAC: Klystron	Research and development on high power klystron.

(d) Research and Development of Detector Technology.

12. LBL: TPC R&D	Research and development on time projection chamber.
13. BNL/FNAL/SLAC	Research and development on colliding detectors.

Table 12 Foreign Visiting Scientists in 1982

	Long Term	Short Term	Total
Foreign Visiting Scientists (MONBUSHO)	15		15
Foreign Researchers (J.S.P.S.)	4		4
Foreign Visitors and Users	11	39	50
Total	30	39	69

Long Term — Longer than one month
Short Term — Shorter than one month
J.S.P.S. — The Japan Society for the Promotion of Science
MONBUSHO — Ministry of Education, Science and Culture

Table 13 FY 1982 Budget

(in thousands of Yen)

		Operation	Capital	Total
Personnel		185,851		185,851
Administration		90,958		90,958
PS	Accelerator & Beams	2,236,563	98,500	2,335,063
	Experimental Equipments	267,421		267,421
	Experiments	956,496		956,496
TRISTAN	Accelerator		4,591,000	4,591,000
	Detectors		672,000	672,000
PF	Linac & Storage Ring	639,113		639,113
	Experimental Equipments		976,800	976,800
	Experiments	171,400		171,400
Booster Utilization Facility		316,568		316,568
Central Computer		606,739		606,739
Radiation & Safety		130,839	207,500	338,339
Cryogenic Services		34,343		34,343
Workshop		9,103	104,000	113,103
Electricity		1,125,338		1,125,338
Electric & Water Plant		449,825		449,825
Site & Buildings		42,840	6,854,932	6,897,772
Specific Projects		59,512		59,512
JAPAN/US Collaboration		1,640,583		1,640,583
Auxiliaries		565,303		565,303
Total		9,528,795	13,504,732	23,033,527

PS Proton Synchrotron PF Photon Factory

Table 14 Number of Staffs in 1983

()Numbers in 1982

	Prof.	Ass. Prof.	Res. Ass.	Officer	Tech.	VS	Total
Director	1						1
General Res. Coordinator	1						1(1)
Physics	4	13	9			5	31(27)
E.P.P.C.	1	2			1		4(7)
Accelerator	6	17	34			4	61(67)
E.R.S.S.	4	5	13				22(21)
Photon Factory	9	10	25			10	54(55)
TRISTAN	4	10	22			3	39(23)
Booster Util. Facility	1	1	4			2	8(7)
Eng. & Tech. Service					95		95(91)
Administration				87	44		131(120)
Total	31	58	107	87	140	24	447(420)

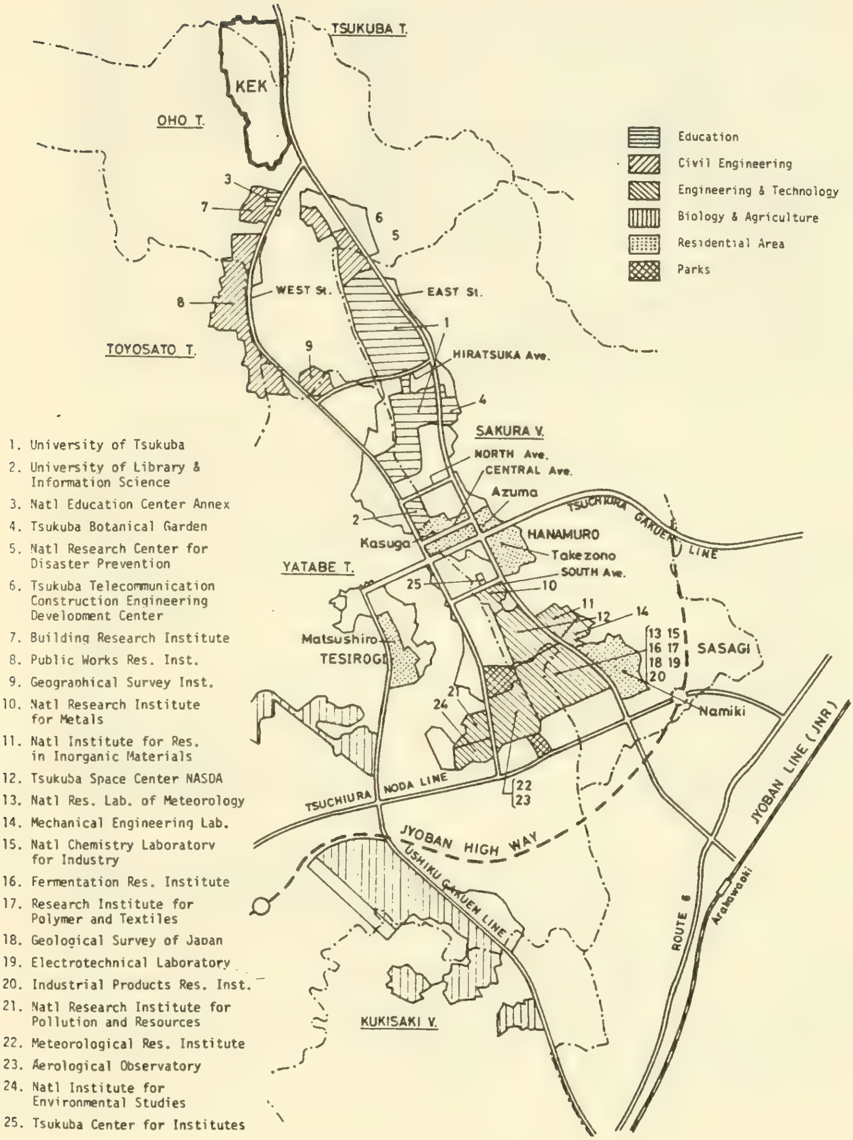
Res. Ass. Research Associate
Tech. Technical
VS Visiting Scientist
E.P.P.C. Experimental Planning & Program Coordination
E.R.S.S. Engineering Research & Scientific Support

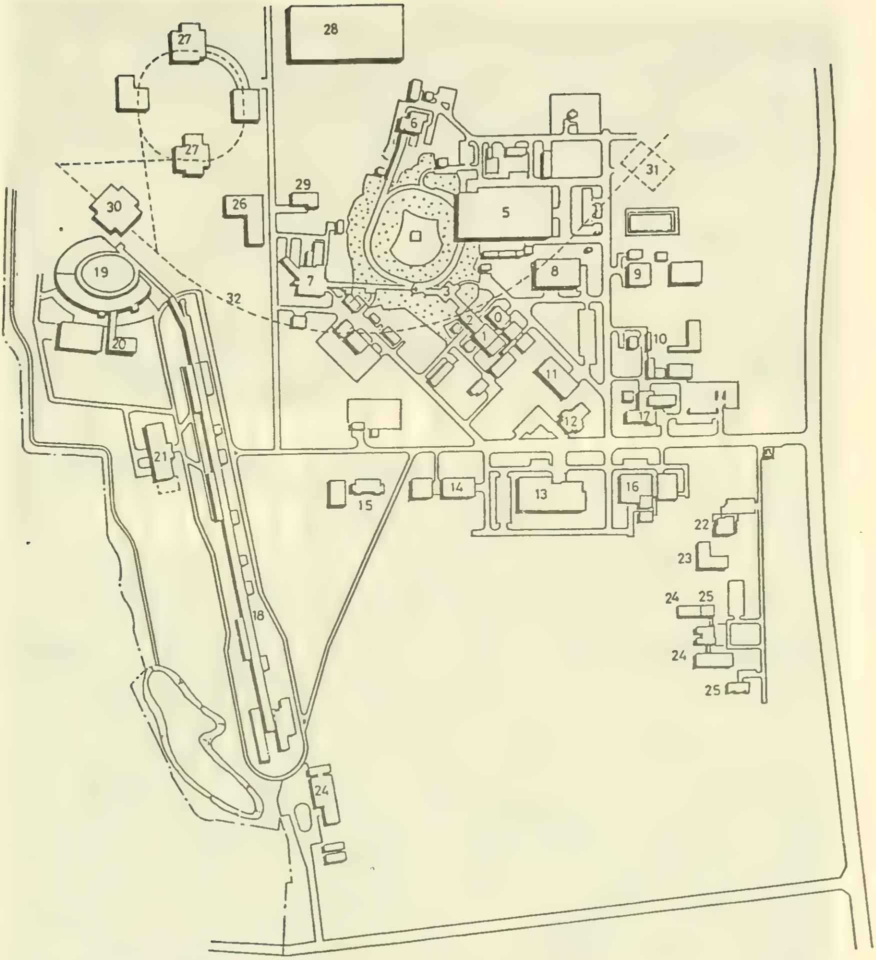
Table 15 Number of Users in 1982

	Prof.	Ass. Prof.	Lect.	Res. Ass.	Tech.	Others	P.F.J.S.	G.S.	Total
PS	28	32	8	54	11	26	4	99	262
BUF	10	16	3	23	4	12	0	41	109
PF	59	59	19	89	8	78	6	96	414
Total	97	107	30	166	23	116	10	236	785

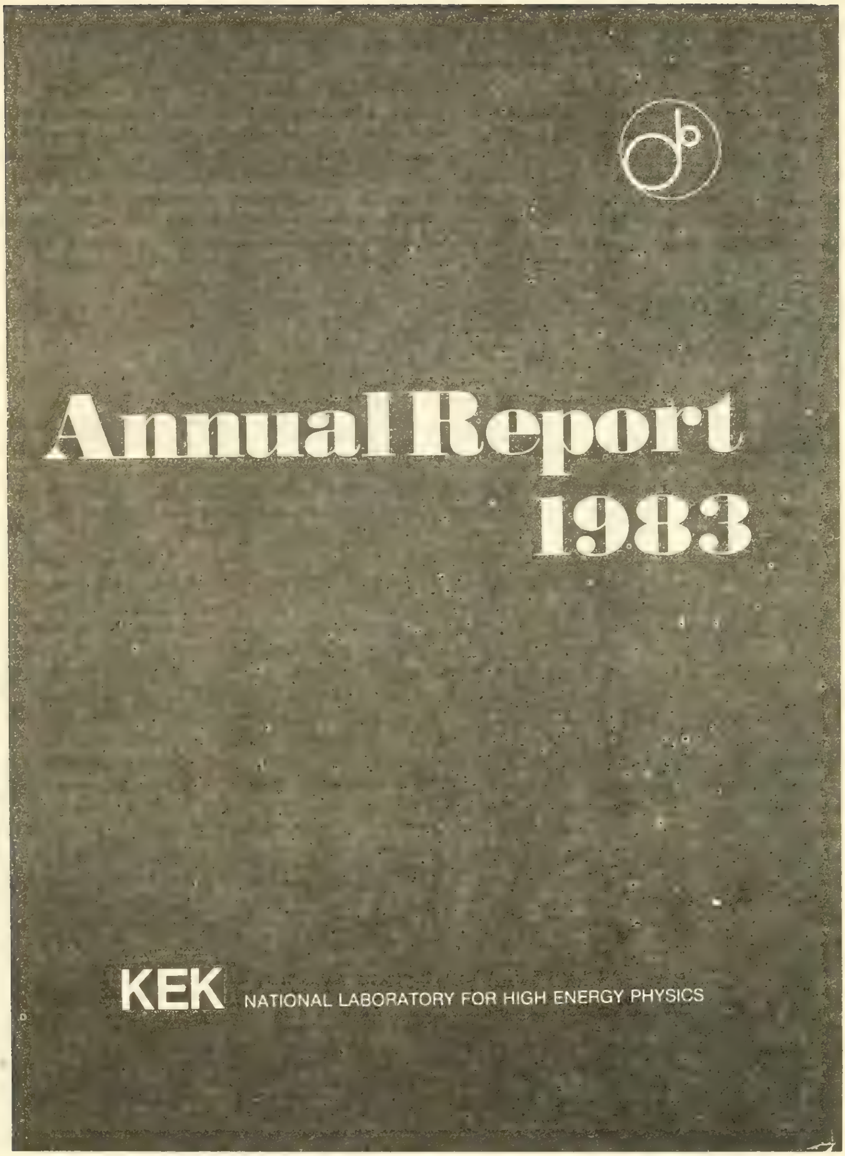
PS Proton Synchrotron BUF Booster Utilization Facility PF Photon Factory
P.F.J.S. Postdoctoral Fellow of the Japan Society for the Promotion of Science
G.S. Graduate Student

Map of the Tsukuba Science City





0. PS Control Room
1. PS Preinjector
2. PS Linac
3. PS Booster
4. PS Main Ring
5. PS Counter Experimental Hall
6. Bubble Chamber
7. Booster Utilization Facility (BSUF)
8. Cooling Water Plant
9. Workshop
10. Helium Liquefier
11. Accelerator Department
12. Accelerator Department & TRISTAN Project Office
13. Physics Department
14. Cryogenic & Vacuum Experimental Hall
15. Radiation Control Center & Chemical Waste Processing
16. Central Computer
17. Administration & Facility Department
18. Electron Linac
19. Electron Storage Ring for Photon Factory
20. Photon Factory Office
21. Cooling Water Plant for PF
22. Cafeteria
23. Staffs & User's Club
24. Guest House (rooms)
25. Guest House (apartments)
26. TRISTAN Control Room
27. TRISTAN AR Experimental Hall
28. Assebly Hall for TRISTAN
29. BSUF Laboratory for Preparation of Experiments
30. TRISTAN MR Experimental HAll (Fuji)
31. TRISTAN MR Exparimental Hall (Oho)
32. TRISTAN MR Tunnel


Annual Report
1983
KEK
NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS

Annual Report

April 1983 - March 1984

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PREFACE

At KEK, this year marked the third year of TRISTAN project which features a large storage ring, roughly 3 km in circumference, for $e^+ e^-$ collisions at 60 GeV in c.m. energy with a conventional RF System. Construction of the main accelerator enclosure, including four large experimental areas, is underway, rather a head of the original schedule. The target date for the first collision is fall of 1986. The Accumulation Ring, construction of which was started in 1981, has been in operation since November 1983. A substantial effort of the accelerator group has been devoted to the RF design and to development of thirty klystrons of 1 MW and a 320 m-long cavity system. In addition, an extensive R&D program for a superconducting cavity is in progress that could raise the maximum attainable energy of the large ring. The TRISTAN Physics Program Advisory Committee (TPAC) held its third and fourth meetings in March and November of 1983, and recommended approval of three major experimental undertakings, i.e. the proposals submitted by the TOPAZ and VENUS Collaborations, both of which are primarily national teams, and the AMY Collaboration, a US based team. These experimental groups have been engaged in the practical design and construction of their detector systems so as to start experiments at $t=0$ of the main-ring operation. It should be noted that all of these experiments use large superconducting solenoids.

The TRISTAN main tunnel will cross a part of the present 12 GeV proton synchrotron complex at about 5 m underneath the existing facilities. The underpinning work will start April, 1984. Before a one year shut down of the 12 GeV PS for this purpose, many active experiments with this machine have been carried out, both in the field of high-energy physics and in intermediate-energy nuclear physics, in particular, with the use of well-separated low energy p and K beams and with the multiparticle spectrometer using a superconducting beam line. Utilization of the booster beam for pulsed neutron scattering experiments, muon science, and cancer therapy and diagnosis has also yielded a large number of important scientific results, including the first trial of medical treatment of patients, in cooperation with the medical group at the University of Tsukuba.

Applications of a high energy accelerator for various fields of science have made great progress at the Photon Factory of KEK. One of the notable features of experiments at the Photon Factory is their interdisciplinary cooperative nature. Many scientists from different fields have collaborated in various types of experiments using the intense beam of X rays and VUV light provided from 9 main beam lines, one of which was constructed with funds from the Nippon Telegram and Telephone Public Cooperation, particularly for the VLSI development. More than 700 users have been registered during this year; 60% of them come from about 50 universities, 30 % from national laboratories, and 10 % from private industry.

As symbolized by the notable discovery of the W and Z particles at CERN this year, which verifies the predictions of the unified theory of electromagnetic and weak forces, it is clear that progress in this field results in deeper understanding of nature at its most fundamental level. In addition, it is clearly shown, through the activities of KEK that engineering and technical development associated with high energy accelerators and detectors cultivates the new age of human technology, culture and industry. We will do our best to promote research in basic science and in the frontier technology of Japan with an international and interdisciplinary outlook.

Finally, beginning this year, I have been asked to continue the laboratory director-ship for the next three year term. As a result of this, some changes in administration framework have been made : Prof. K. Kikuchi will be the General Research Coordinator, Prof. S. Ozaki will be the Chief Director of the TRISTAN Project, and Mr. S. Ueda will be the Director of the Administration Department. It should also be noted that Prof. T. Mukaibo, the former President of the University of Tokyo, was nominated as the Chairman of the Board of Councilors to succeed Prof. K. Husimi who had been the Chairman since 1974 and was returned to the House of Councilors in Japan. At the end of this fiscal year, three distinguished professors, Profs. K. Kohra, A. Kusumegi and S. Yasumi

retired. On behalf of the laboratory, I would like to express our deepest thanks to these outstanding scientists who really shaped the history and development of KEK since its inception.

Tetsuji Nishikawa
Director General

Topics in FY 1983

April 18, 1983

Mr. M. Setoyama, Ministry of Education, Science and Culture visits KEK.

June 18, 1983

Dr. C. Rubbia visits KEK and reports on the discovery of $W^{\pm}$ and Z^0 particles in the UA 1 experiment at CERN.

November 4-5, 1983

The 1st Photon Factory Symposium is held at Tsukuba Center for Institutes. Dr. I. Lindau, associate director of SSRL, is discussing at the poster session.

November 18, 1983

TRISTAN Accumulation Ring succeeds in accelerating electron to 4.2 GeV just two years after the ground breaking on November 13, 1981.

Outline of KEK

Aerial view of KEK

General Introduction

National Labortory for High Energy Physics (KEK) was established on April 1, 1971, as a national center of high energy physics open to users from universities and other institutions. The Laboratory is the first institute of eleven "Interuniversity Research Institutes" supervised by the Ministry of Education, Science and Culture (MONBUSHO). It is located at the northern boundary of Tsukuba science city and the site is an approximate rectangle of 1 km × 2 km.

KEK was origninally established for the purpose of promoting experimental studies on elementary particles and 12 GeV proton synchrotron was constructed as the first major facility. For this new project a capital budget of 13 BY was allocated from FY 1971 to FY 1975. The first 8 GeV (original design value) beam was obtained in March 1976 and physics experiments started in May 1977. The TRISTAN project, a 30 GeV electron-positron colliding accelerator, was approved by the Government as a five-year construction program and the ground was broken in November 1981.

In addition to research into the fundamental aspects of particle physics, in 1978 were established the Photon Factory and the Booster Synchrotron Utilization Facility in order to cover various fields of research activities with the use of high energy accelerators. The Booster Synchrotron Utilization Facility, which makes use of 500 MeV booster beam of the proton synchrotron, includes studies on neutron diffraction, pion and muon physics and cancer therapy. The Photon Factory is for research with synchrotron radiations, and a 2.5 GeV electron linac and a storage ring were constructed for four years from 1978 with a budget of 20 BY.

The organization of KEK is shown in Fig. 1. It has two covering structures appointed by the Minister of MONBUSHO. Board of Councilors is an advisory council for the laboratory director and consists of fifteen members, who are presidents of universities, directors of other laboratories in the related fields and other eminent scholars, and gives advices to the director with respect to the policy of KEK and nominates the director of KEK. Advisory Council for Scientific Policy and Management is for discussing scientific policy and management of KEK and consists of twenty-one scientists. Eleven of the members are scientific staffs of KEK and the other half are elected from user's group. The Council summarizes and represents opinions of high energy physicists with respect to the scientific program and operation of KEK, and gives the recommendation to the director on employment and promotion of scientific staff members of KEK.

The original KEK started with four departments; i.e., Accelerator Department, Physics Department, Engineering Research and Scientific Support Department and Administration Department. In April 1977, a reorganization of the laboratory created the Program Coordinator's Office for the coordination of experimental program and a new department, Engineering and Technical Service Department grouping all engineers and technicians working in cooperation with other research departments. In 1978 the Booster Synchrotron Utilization Facility and the Photon Factory consisting of three departments; Injector Linac Department, Light Source Department and Instrumentation Department, were established.

In Table 1 is shown the budget of KEK in FY 1983 and Fig. 2 illustrates the annual trend of the budget. In Table 2 and 3 are shown the number of staffs of KEK and number of users in FY 1983 respectively.

History

May, 1962	The Science Council of Japan recommended the Government to promote future programs of high energy and nuclear physics which included construction of a high energy proton accelerator.
September, 1963	The Government decided to construct a new science city in Tsukuba district with an area of about 4000 ha and ordered the Japan Housing Agency to buy the land.
April, 1964	The Government allocated a budget for basic studies of the high energy accelerator, and a working group was organized in the Institute for Nuclear Study, University of Tokyo. For this new project a total amount of 140 MY was funded for the period of 1964-1969.
May, 1968	The site of the new institute for high energy physics was decided.
August, 1969	The Science Council of MONBUSHO advised the Minister to establish a new institute of elementary particle physics with a proton accelerator with a quarter of the budget of the original plan.
April, 1970	MONBUSHO started the construction of the pre-injector housing of the accelerator.
April, 1971	National Laboratory for High Energy Physics (KEK) was established as the first Interuniversity Research Institute. Dr. S. Suwa was appointed as the Director General.
August, 1974	The injector linac accelerated protons to 20 MeV.
December, 1974	The booster synchrotron accelerated protons to 500 MeV.
March, 1976	The main synchrotron (main ring) accelerated protons to 8 GeV as designed.
December, 1976	The main ring accelerated protons to 11.8 GeV.
April, 1977	Dr. T. Nishikawa was appointed at the Director General.
May, 1977	Physics Experiments of proton synchrotron started with an internal target beam for counter experiments and a fast extracted beam for bubble chamber.
April, 1978	Booster Synchrotron Utilization Facility and Photon Factory were established. Counter experiments with the slow extracted beam started.
October, 1978	Continuous 12 GeV run started and kaon beam lines became available.
April, 1979	A working group was organized for the future plan of KEK, TRISTAN.
November, 1979	An Implementing Arrangement for the JAPAN/US Cooperation in the Field of High Energy Physics was signed at SLAC between MONBUSHO and the US Department of Energy.
October, 1980	Experiments with pulsed neutrons and pulsed muons started at the Booster Utilization Faiclity.
April, 1981	The TRISTAN project was approved by the Government and the construction started. February, 1982 The 2.5 GeV electron linac and the storage succeeded in operation and test experiments started.
October, 1982	Experiments with synchrotron radiations started.
November, 1983	The TRISTAN Accumulation Ring accelerated electrons to 4.5 GeV.

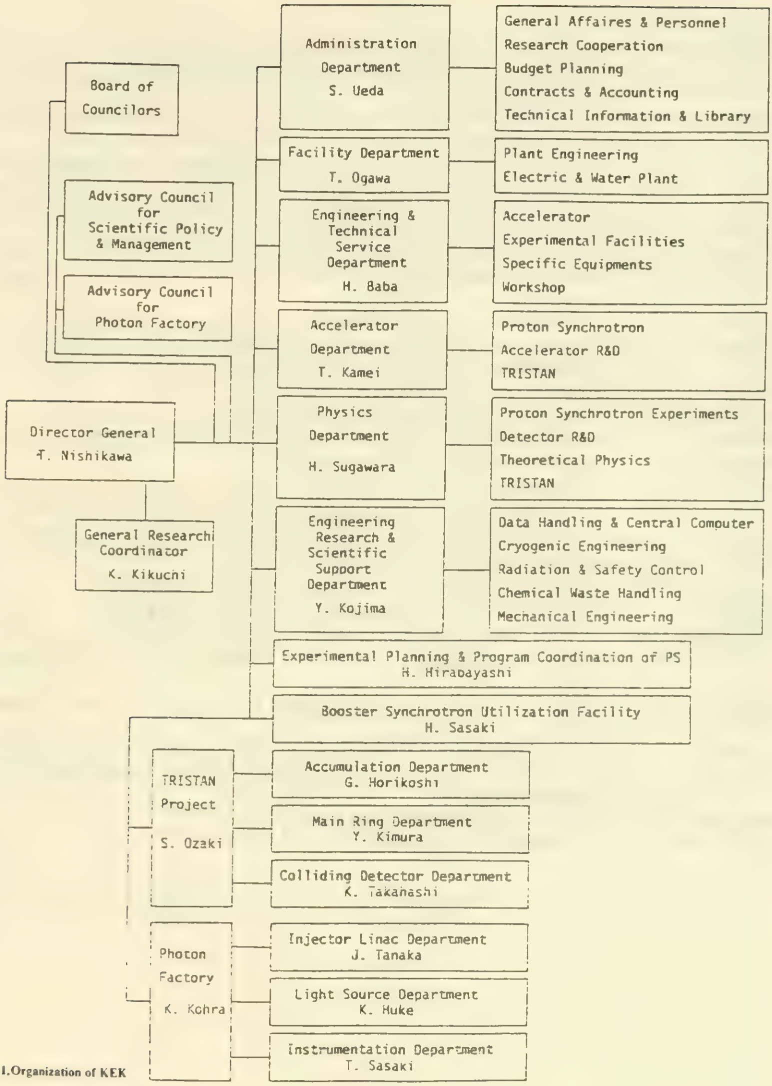


Fig. 1.Organization of KEK

Table 1. FY 1983 Budget

(in thousands of Yen)

		Operation	Capital	Total
Personnel		1,924,537		1,924,537
Administration		100,234		100,234
Proton Synchrotron	Accelerator & Beams	2,083,811		2,083,811
	Experimental Equipments	268,501		268,501
	Experiments	875,896		875,896
TRISTAN	Accelerator	239,908	5,566,450	5,806,358
	Detectors		2,290,550	2,290,550
Photon Factory	Linac & Storage Ring	603,011		603,011
	Experimental Equipments	135,258		135,258
	Experiments	192,052		192,052
Booster Synchrotron Utilization Facility		255,580		255,580
Central Computer		606,161		606,161
Radiation & Safety		144,073	211,912	355,985
Cryogenic Services		47,306	200,000	247,306
Workshop		8,648	48,450	57,098
Electricity & Water		2,009,405		2,009,405
Electric & Water Plant		460,514		460,514
Site & Buildings		203,143	10,907,300	11,110,443
Specific Projects		54,506		54,506
JAPAN/US Cooperation		1,564,127		1,564,127
Auxiliaries		654,312		654,312
Total		12,430,983	19,224,662	31,655,645

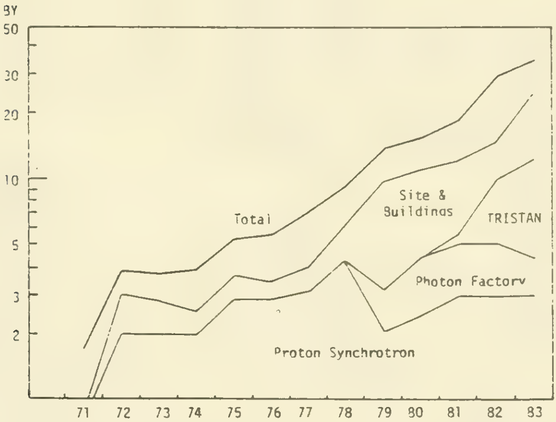


Fig. 2. Annual Trends in Budget

Table 2. Number of staffs in 1938

( ) Numbers in 1982

	Prof.	Ass. Prof.	Res. Ass.	Officer	Tech.	VS	Total
Director	1						1
General Res. Coordinator	1						1(1)
Physics	4	13	9			5	31(27)
E.P.P.C.	1	2			1		4(7)
Accelerator	6	17	34			4	61(67)
E.R.S.S.	4	5	13				22(21)
Photon Factory	9	10	25			10	54(55)
TRISTAN	4	10	22			3	39(23)
Booster Util. Facility	1	1	4			2	8(7)
Eng. & Tech. Service					95		95(91)
Administration				87	44		131(120)
Total	31	58	107	87	140	24	447(420)

Res. Ass. Research Associate
Tech. Technical
VS Visiting Scientist
E.P.P.C. Experimental Planning & Program Coordination
E.R.S.S. Engineering Research & Scientific Support

Table 3. Number of users in 1983

	Prof.	Ass. Prof.	Lect.	Res. Ass.	Tech.	Others	P.F.J.S.	G.S.	Total
PS	29	49	9	60	11	7	3	88	256
BUF	21	23	2	26	3	12	0	42	129
PF	57	62	13	101	20	53	1	152	459
TRISTAN	23	17	2	20	8	1	0	39	110
Total	130	151	26	207	42	73	4	321	954

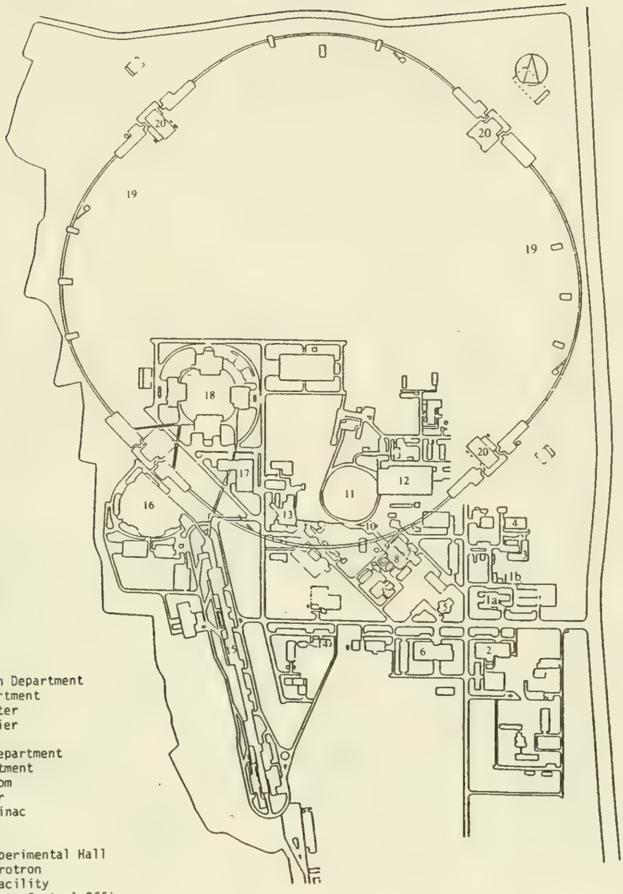
PS Proton Synchrotron
BUF Booster Utilization Facility
PF Photon Factory
R.F.J.S. Postdoctoral Fellow of the Japan Society for the Promotion of Science
G.S. Graduate Student

Table 4. Foreign visiting scientists in 1983

	Long Term	Short Term	Total
Foreign Visiting Scientists (MONBUSHO)	15	1	16
Foreign Researchers (J.S.P.S.)	2	0	2
Foreign Visitors and Users	2	80	82
Total	19	81	100

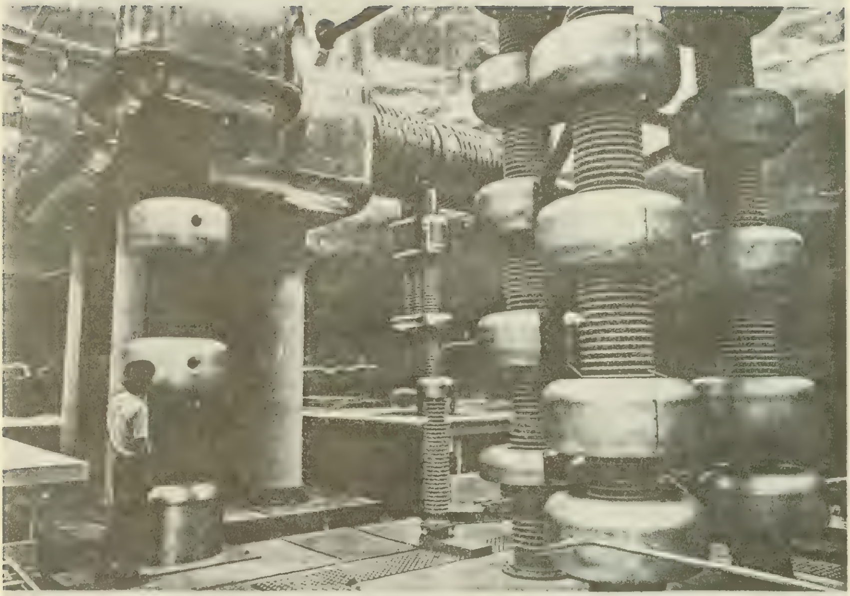
Long Term Longer than one month
Short Term Shorter than one month
J.S.P.S. The Japan Society for the Promotion of Science
MONBUSHO Ministry of Education, Science and Culture

Buildings



1a. Administration Department
1b. Facility Department
2. Central Computer
3. Helium Liquefier
4. Work Shop
5. Accelerator Department
6. Physics Department
7. PS Control Room
8. PS Preinjector
9. PS Injector Linac
10. PS Booster
11. PS Main Ring
12. PS Counter Experimental Hall
13. Booster Synchrotron Utilization Facility
14. Radiation Safety Control Office
15. PF Electron Linac
16. PF Electron Storage Ring and Experimental Hall
17. TRISTAN Control Room
18. Accumulation Ring
19. Electron-Positron Colliding Ring
20. TRISTAN Experimental Halls

Accelerator Department



Cockcroft Preinjector for polarized H^- beam

The KEK 12 GeV Proton Synchrotron Complex (Injector, Booster and Main Ring) was operated for 3300 hours with low failure rate 3 % in FY 1983. It fed 1.2 × 10^{19} protons to the various scientific programs-elementary particle and nuclear physics and more than 6.1 × 10^{19} protons from the Booster to applied nuclear physics, material science and medicine.

Various studies were done for improvements of the PS performances. The RFQ cavity is being fabricated and a permanent quadrupole magnet has been installed in the drift tube at high energy end of the Linac cavity. Design study of the additional Linac cavity increasing energy from 20 MeV to 40 MeV has been executed with the half size model cavity and this energy increase is very desireable for charge exchange injection to the Booster. The first trial of charge exchange injection to the Booster were made and in spite of low injection energy 20 MeV the injected beam was stacked for more than one hundred turns. Acceleration of the polarized protons in the Linac and the Booster was tested for the first time and the polarizations of the Linac and Booster beam were measured. One depolarization resonance in the Booster was observed besides two strong resonances that were anticipated and studies showed depolarization due to the third resonance could be reduced by installation of a pulsed quadrupole magnet in the Booster.

Accelerator Operation

The proton synchrotron (PS) was operated for about 6.5 months (thirteen cycles) in total, and the regular cycle was ten-day operation for every two weeks. Besides the regular cycle, the PS was operated for the study of the charge exchange injection and the acceleration of the polarized protons for three cycles in September and October. Moreover a half cycle operation in January was dedicated for the medical use of the Booster Synchrotron Utilization Facility (BSF).

As about half of the PS staffs have collaborated with the TRISTAN construction, the maintenance and the improvement of the PS are performed by the rest, and the operation duty is equally shared by them.

The machine operation statistics are given in Table 1 and Fig. 1, and the statistics from FY 1977 to FY 1983 are reviewed in Fig. 2. In the same manner as in the previous year, the machine down time concerning the Booster occupied more than a half of the total due to its full rate operation (20 Hz) for the BSF. The total of accelerated protons in the Booster and in the Main Ring was 60.7×10^{18} particles and 11.5×10^{18} particles respectively.

Table 1

Total operation hour	3315 hrs
Beam Utility	2509 hrs
Slow Extraction	2509 hrs
Internal Target	2491 hrs
BSF (Including parasite)	2711 hrs
Accelerator Study	374 hrs
Accelerator Failure	94 hrs
Accelerator Tuning	167 hrs
Others	171 hrs
Average Intensity	
Main Ring	3.3×10^{12} ppp
Booster	5.3×10^{11} ppp

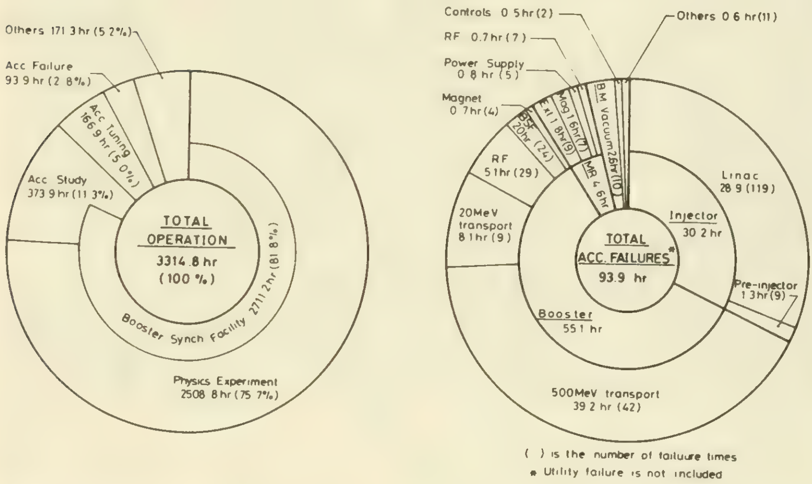


Fig. 1. Operation statistics in FY 1983.

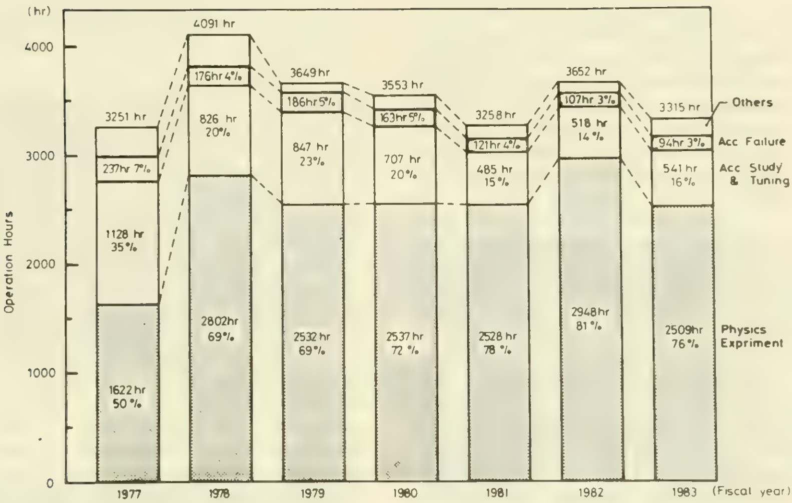


Fig. 2. Review operation statistics since 1977.

Injector

The beam transport line for 750 keV polarized beams was connected to the old beam transport line. Thus it became possible to inject polarized or ordinary beams to Proton Linac.

Polarity of Cockcroft Preinjector was reversed for a month to test charge-exchange injection of H^- to Booster Synchrotron. Based on the result, conversion from protons to H^- was finally decided. It is well known that higher injection energies are favorable for the charge-exchange injection because of both lower energy loss and smaller multiple scattering in a charge-stripping foil. Then, an additional linac tank was designed to increase the injection energy from the present 20 MeV to 40 MeV. It is a 13 m long Alvarez linac with 35 cells. The computer codes are SUPERFISH and PARMILA. To fix design of post couplers, which stabilize field distribution against perturbation, a 400 MHz model cavity of 15 cells was made. It was verified that the post couplers work well. As the H^- current is 10 ~ 20 % of the present proton current, beam loading will decrease in the Linac tank. 20 MeV Proton Linac has been excited by two TH516 high power RF systems. Its excitation power is 1 MW whereas the beam power is 2.5 ~ 3 MW for the proton beam and 0.6 MW or less for the H^- beam. Thus one high power RF system is enough for driving the 20 MeV Linac and the other can be used for the additional tank. The new tank will be excited by two-feed system as the 20 MeV Linac tank. Each RF high power will be divided by a power splitter, transferred through circulators with dummy loads and coupled to the tank.

Drift tubes will be equipped with permanent Q magnets. Although the ALNICO magnet is not so strong as the REC magnet, it can yield the maximum design field gradient of 2.2 kG/cm in a Q magnet of 35 mm aperture. It can be magnetized or demagnetized in the linac tank. This is advantageous for assembling the drift tubes and aligning them in the tank. An ALNICO Q magnet was installed to the last drift tube of the 20 MeV Linac tank. It has worked already for a half year without trouble.

As the first step of the RF system renewal program, the power supply of the buncher was replaced. It has three RCA 7651 amplifiers, one for the debuncher and the others for the prebuncher. They are carefully shielded to reduce RF leakage.

An radiofrequency quadrupole linac (RFQ) is being made. Its injection and final energies are 50 and 750 keV. It is to be used as the third injector of Proton Linac.

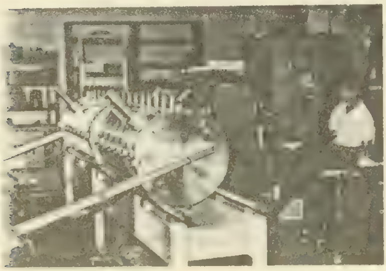


Fig. 3. 400 MHz, 15 cell model Alvarez linac cavity. Field distribution is being measured by standard bead perturbation method.

H^- Charge-Exchange Injection

Charge-exchange injection of H^- is an attractive method to increase beam intensity in a proton synchrotron with lower beam loss at injection. To apply it to Booster Synchrotron, a multicusp H^- ion source was developed and installed directly to the high gradient accelerating column for the conventional duoplasmatron. It has a molybdenum converter with cesium layer. When its cathode filament was heated by an alternating-current of 50 Hz, beam intensities scattered from pulse to pulse and life of tungsten filament was unexpectedly short. These were eliminated by direct-current heating. After suitable preparation of the converter, a 20 mA H^- beam was extracted from the source and accelerated to 750 keV. It was very stable. Its normalized emittance was 0.17 π cm·mrad at the entrance of Proton Linac. As the beam width should be extended from 5 μs of protons to 100 μs of H^- ions, the RF system of Proton Linac was slightly modified and adjusted. 8.5 mA H^- out of the injected beam was accelerated to 20 MeV.

The first test experiment on the H^- charge-exchange injection at Booster Synchrotron was carried out during three weeks from the end of September 1983. The system for the multi-turn injection by protons was replaced by an H^- charge-exchange injection system, which consists of four orbit bump pulsed magnets, a septum magnet, a set of profile monitors, a charge stripper foil holder and a new-foil magazine. H^- ion beam delivered from the 20 MeV injector linac ranged from several hundred μA to several mA, and reached 8 mA at the end of the test period. In order to understand the accumulation process of proton beam in Booster, measurements were done on various kinds of items; emittance of the 20 MeV H^- ion beam, beam size of stacked beam, energy loss of stacked beam in traversing the stripping foil, injected beam pulse width- and intensity-dependence of stacking efficiency, etc. Particularly, the measurement of the energy loss of the stacked beam in traversing a 120 μg/cm^2 thick stripping foil offered an information that the hitting probability of circulating proton beam on the foil was unexpectedly low, namely, the protons hit the foil every four revolutions. This fact in combination with the experimental results of the stacking efficiency led to a conclusion that a large injection error took place and the betatron oscillation amplitude induced by this error was estimated to be 10 mm to 37 mm which should be compared with the effective horizontal semi-aperture of 40 mm in Booster. It was also found that the stacking efficiency started to decrease with the increase of stacked protons at the intensity level of about 1.3×10^{12} protons. While the stacked beam by the multi-turn injection with proton is at around 1.4×10^{12} protons in the typical operation, the maximum stacked beam intensity of 2.1×10^{12} protons was attained with a 8 mA 100 μs wide H^- ion beam. In spite of a beam loss during acceleration due to an accidental trouble in the RF accelerating system, the maximum output intensity of 7.1×10^{11} protons per pulse was recorded as shown in Fig. 5 at the end of the test period, which is a new record in Booster Synchrotron. The charge-exchange injection has never been tried with such low injection energy as 20 MeV. However, the test experiment has proved this injection method appears to be quite

promising for increasing the beam intensity of Booster Synchrotron.

Fig. 4. Multicusp H^- ion source ready to mount to the high gradient accelerating column. it delivered stable 20 mA H^- beam.

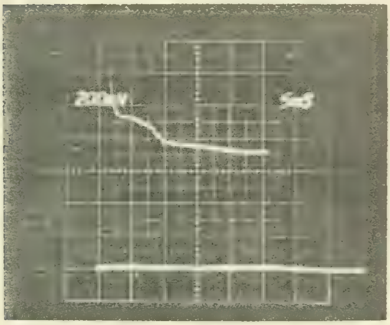


Fig. 5. Accelerated proton beam at the achievement of the intensity record in Booster Synchrotron. Horizontal scale: 5 ms/div., vertical scale: 2 × 10^{11} protons/div.

Acceleration of Polarized Proton Beam

The optically pumped polarized ion source has been developed for high intensity polarized H^- beams. It consists of four parts, a 16.5 GHz ECR proton source, a Na cell and lasers which polarize valence electrons of sodium atoms, ordinary zero-crossing magnetic fields and the other Na cell for production of negative ions. It was already installed in the high voltage terminal of 750 kV Preinjector in FY 1982. The source has been improved further as follows. A single hole extracting electrode of the ECR source was replaced by a set of three electrodes with multi-slits. The ECR source itself was equipped with multicusp magnetic field. A recycling system was introduced to the Na cells for longer term operation. A closed loop was made for stable operation of the laser. It includes a single frequency dye laser, a wave meter and a personal computer. It almost removed frequency shifts caused by mode hop of the laser. A 40 m beam line was assembled. It guides the polarized beam from the Wien filter, which follows the accelerating column, to 20 MeV Proton Linac. It was tuned to 750 keV H^- ions by computer (ECRIPS S-140) system. The ion source is controlled by the same system through optical fibers. High gain current transformers (5 μA/V) and sensitive beam profile monitors were developed satisfactorily. Figure 6 shows dependence of the polarization and beam intensities on beam sizes.

The first acceleration test of polarized protons was performed in KEK Proton Synchrotron. Since the study time, about three weeks, was not enough to investigate depolarizations both in Booster and Main Ring, depolarization in 500 MeV Booster Synchrotron was investigated as the first step of this program. The polarized H^- beam accelerated by 20 MeV Proton Linac is injected into Booster Synchrotron with a charge-exchange injection. The polarized proton was accelerated up to 500 MeV in Booster and then injected to Main Ring. The polarization of the Linac beam was measured by the 20 MeV polarimeter which was installed in the beam transport line from Linac to Booster. In order to investigate depolarization, an internal polarimeter is installed in the long straight section II-2F of Main Ring. Depolarization in Booster was investigated by measuring beam polarization at 500 MeV with the coasting beam in Main Ring.

The intensities of polarized proton beam at various stages of the accelerator were as follows:

ION SOURCE	(H^- ↑, 750 keV)	5—10μA (pulse duration 75 μs),
LINAC	(H^- ↑, 20 MeV)	0.5—1μA (pulse duration 75μs)
BOOSTER	(p↑, 500 MeV)	1 3 × 10^{18} p/bunch
MR	(p↑, 500 MeV)	1—2 × 10 p/bunch.

We have not installed any equipment to reduce depolarization in Booster because spin-flip is expected for the two strong resonances at $\gamma G = 2$ (108 MeV) and $\gamma G = \nu_z$ ($\sim$ 260 MeV). The polarizations of the polarized beam were

LINAC	p(LINAC, 20 MeV)	$= 47 \pm 6$–56 ± 8 %
MR	p(MR, 500 MeV)	$= 12 \pm 2$–15 ± 2%.

About 25 % of the Linac beam polarization was kept in Main Ring at 500 MeV. In order to investigate the resonance strengths, the beam polarization was measured by varying the vertical beam size using the fast rotating-beam-scraper and by varying the vertical closed orbit distortion (COD) using a pulsed dipole magnet (vertical deflector) in Booster.

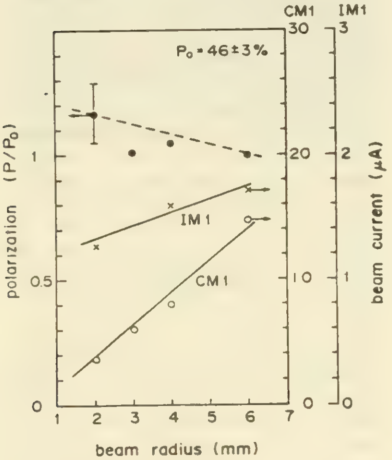


Fig. 6. Dependence of polarization and beam currents on beam sizes at the optically pumped polarized ion source. IM1 shows the current just after 750 kV acceleration whereas CM1 is 20 MeV Linac beam. Polarization is rather uniform over the radius.

Figure 7 is the dependence of the beam polarization at 500 MeV on the vertical beam size in Booster. The polarization is positive if the polarization flips on passing through two strong resonances in Booster. This result shows that the resonance strength of the intrinsic resonance $\gamma G = \nu_z$ is strong enough for spin-flip since the beam polarization flips on crossing this resonance until the vertical beam emittance decreases to about 1/100 of usual one.

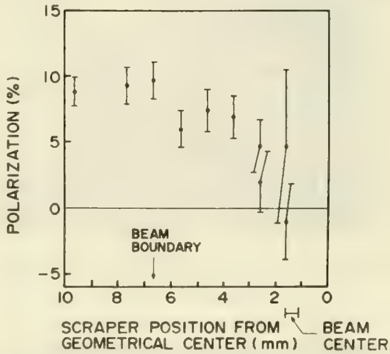


Fig. 7. Dependence of 500 MeV beam polarization on the vertical beam size in Booster Synchrotron. Polarization was measured in Main Ring with the coasting beam at the injection energy of 500 MeV. Beam size was varied by adjusting the insertion of the rotating-beam-scraper into the beam in Booster.

Figure 8 is the dependence of the polarization on the excitation current of the vertical deflector. The imperfection resonance $\gamma G = 2$ in Booster is also strong enough for spin-flip. At the excitation current of 169 A, the resonance strength of the imperfection resonance became weak and polarization reversed since the vertical COD was reduced at this current.

In order to investigate the large depolarization in the booster, we changed the vertical tune γ_z by exciting the correction quadrupole magnet above 250 MeV. Figure 9 shows the dependence of the polarization on the excitation current of this magnet. About 40 % of the Linac beam polarization was kept in Main Ring at 500 MeV at the excitation current of 60 A. It is expected from this result that other weak resonances, for example the $\gamma G = 5 - \nu_z$ resonance due to the symmetry breaking of the machine or the resonances due to the sextupole field, cause large depolarization. In order to reduce depolarization by such resonances, we are planning to install the pulsed quadrupole magnet in Booster in 1984. Moreover, we

have to develope the beam monitoring system for RF control of Main Ring to accelerate the low intensity beam of < 10^9 p/bunch stably since S/N ratio of the presnt beam monitoring system is not enough for RF control.

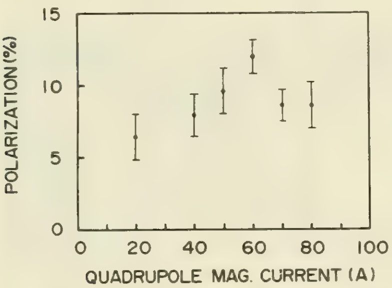


Fig. 8. Dependence of 500 MeV beam polarization on the excitation current of the vertical deflector which generates the vertical closed orbit distortion in Booster.

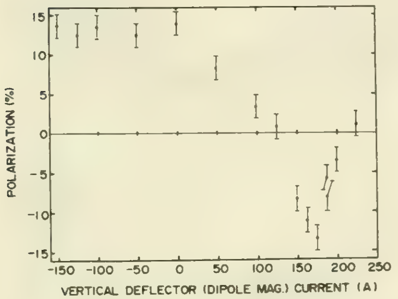


Fig. 9. Dependence of 500 MeV beam polarization on the excitation current of the correction quadrupole magnet in Booster which was excited in the energy region above ~ 250 MeV.

Superconductive Energy Storage

Optimization of Superconductive Magnetic Energy Storage (SMES) System

The capital cost of the SMES system depends on many kinds of factors. The main contributed factors to the cost are superconductor, supporting structure for magnetic force, construction in rock and a site, and related to a parameter of aspect ratio which is defined as the ratio of the height to the diameter of the solenoid. Then the capital cost of the system is a function of the aspect ratio. The study revealed the optimum value of the aspect ratio as shown in Fig. 10.

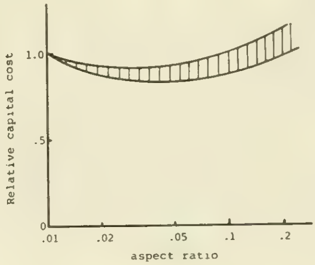


Fig. 10. Relative capital cost of SMES vs. aspect ratio.

Study of protection of superconductive coils

Superconductive coils quench when thermal or mechanical disturbances result in forcing the coils unstable. In some cases, the quenched coils have been damaged by thermal stresses or electrical breakdown. The simulation has been performed for protecting coils from damage caused by the quench. Such quench mechanism and protection methods will be investigated by using the model magnet which has been built according to the results of the simulation.

TRISTAN Project

TPAC (TRISTAN Physics Program Advisory Committee)

Prof. [illegible] presented the AMY [illegible] for the [illegible] TRISTAN experiment [illegible] TPAC meeting [illegible] November 1983

Tuning work for the first beam in Accumulation Ring

The TRISTAN project has been put under a new project organization scheme since April 1, 1983, in order to provide more cohesive execution of the project and to establish a clear line of responsibility. Although the project has continued to be carried out in close collaboration with other departments at the laboratory, (particularly of the Accelerator Department and the Physics Department) the Accumulation Ring Department, the Main Ring Department, and the Colliding Beam Detector Department became the centers of activity for construction of the accelerators and detectors, respectively, under the project directorship. Thus, starting with this topic, activities related to the TRISTAN project will be summarized in subsequent sections, each under its own heading.

With substantial increase in budget and man power, the construction of the TRISTAN accelerators and detectors has shown a major step forward. Highlights of the progress on the project for this year include the commissioning of the Accumulation Ring on November 18, 1983. Exactly two years from the date of ground breaking for this ring, construction of the Accumulation Ring complex was completed and an acceleration of electrons to 4.2 GeV was successfully achieved, establishing a world record for the construction speed of an accelerator of this magnitude. In the area of the Main Ring, two of the four experimental halls, and the west tunnel are taking shape and the civil construction on the rest of the experimental halls and tunnels began. By the end of the fiscal year, the shape of the entire Main Ring complex became visible. Regrettably, however, construction of the south tunnel compelled the 12 GeV Proton Synchrotron to be shut down, stopping all research activities with this complex, since the tunnel has to be dug under the existing structure of this accelerator. A major portion of the Main Ring magnets has been delivered, tested, and stored in an assembly hall, waiting for installation in the tunnel. The 6000 square meter assembly hall was completed during this fiscal year as a staging area for the TRISTAN accelerators and experiments. A building to house a 200 MeV Linac for positron generation is almost complete at the upstream end of the 2.5 GeV electron Linac.

With extension of the capabilities of TRISTAN in mind, an intensive development program for superconducting RF cavities has continued and another program for superconducting quadrupole magnets was initiated. The cavity will enhance TRISTAN's energy capability and the quadrupole will enable us to use mini, or micro beta optics for higher luminosity.

In the area of detector development, we have started to receive deliveries of equipment from manufacturers. The first major item received was the shell structure of the central drift chamber for VENUS, which measures 2.5 meters in diameter and is 3.0 meters in length.

The fourth meeting of TPAC was held on November 8-10, 1983, and recommended approval of a proposal presented to it by Prof. S. Olsen of Rochester University, U.S.A., for the AMY collaboration. The AMY program is to be supported under the cooperation of the U.S.A. and Japan.

The project as a whole, including the civil construction of facilities and the preparation of technical components for the Main Ring and detectors, is progressing steadily and well. The detailed progress made in each area of the project will be presented in the reports which follow.

ACCELERATORS

Overview of the Project

The TRISTAN project as currently envisaged is to construct an electron-positron colliding beam accelerator with the center of mass energy in the range of 60 GeV. The project was approved by the Government and began in April 1981 as a five-year program.

The accelerator complex consists of four accelerator units. Electrons and positrons are accelerated to 2.5 - 3 GeV in an electron linac which is currently used for the Photon Factory and injected into the Accumulation Ring. Positrons are produced by a high intensity electron linac of 200 MeV, which is being constructed with the target date of completion in FY 1984. The Accumulation Ring (AR) is a storage accelerator of 377 m in circumference and accelerates electrons and positrons to 8 GeV prior to injection into the main electron-positron colliding beam ring. The Main Ring (MR) has a circumference of 3 km. Four arcs of 347 m in average radius are joined by four long straight sections of 194 m in length. Two electron and two positron bunches circulating in the opposite direction will make collisions to each other at the middle of four straight sections. A major part of each straight section will be filled with rf accelerating cavities, leaving relatively short section to install a colliding beam detector. The Accumulation Ring is in operation. The civil construction of accelerator tunnels, associated facilities, and experimental halls as well as the fabrication of accelerator technical components and detectors are in progress.

Table 1. Design parameters of the TRISTAN MR and AR

	Main e^+e^- collider	Accumulation ring
Circumference	3018.1m	377.0m
Average radius of curved section	346.7m	47.7m
Long straight sections	4 × 194.4m	2 × (19.5m + 19.1m)
Total length of RF sections	320m	30m
RF frequency	508.6MHz	508.6MHz
Injection energy	6—8 GeV	2.5—3 GeV
Maximum energy	25—30 GeV	6—8 GeV
Number of interaction regions	4	2
Max. design luminosity	8×10^{31} cm^{-2}·s^{-1}	2×10^{31} cm^{-2}·s^{-1}

A site layout of the TRISTAN complex is shown in Fig. 1. Design parameters of the AR, MR are listed in Table 1.

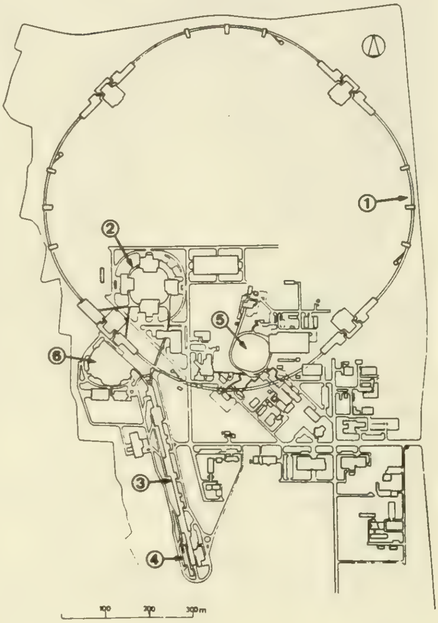


Fig. 1. Site layout of the TRISTAN project. 1. TRISTAN MR. 2. TRISTAN AR. 3. 2.5 GeV Electron linac. 4. Positron source linac. 5. 12 GeV Proton Synchrotron. 6. Photon Factory electron storage ring.

Accumulation Ring

The TRISTAN Accumulation Ring, AR, came into operation for beam test in October 1983. The beam commissioning took place as follows.

Oct. 19 and 26
Transport of a 2.5 GeV electron beam from the injector linac to the AR injection point. The operational parameters of the beam transport line were settled.

Nov. 9 and 11
Tuning of the injection and main lattice elements for a full beam turn in AR. The beam was observed to survive for about 500 μsec after injection with no rf acceleration.

Nov. 16 and 18
Accumulation and acceleration of the beam were tried with an rf acceleration. An accumulated beam of about 0.5 mA was successfully accelerated to 4.2 GeV, which was limited by a capability of the rf system installed. Figure 2 shows a synchrotron light spot of the circulating beam seen on a TV screen.

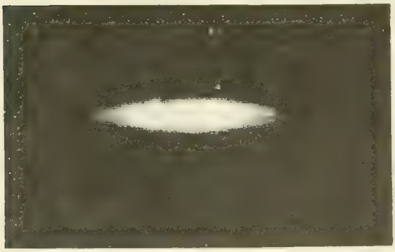


Fig. 2. Synchrotron light spot of the AR circulating beam seen on a TV screen.

Through the initial operation, it was proved that the whole AR system worked duly as designed. Especially such a smooth beam commissioning was enabled by the wholly computerized control system which had newly been developed. Figure 3 shows an example of the control panel. Horizontal and vertical betatron functions (β_x, β_y) and dispersion function (η_x) are plotted on the graphic display. All the control functions are executed through the touch panels as shown below the display.

After the commissioning, AR had been operated about 50 hours for every week till the end of March 1984. The operating time was put in accelerator studies and preparation of two internal target beam lines to provide high energy electrons for calibration of lead glass counters.

The results of accelerator studies are summarized as follows.

Maximum energy
An acceleration to higher energies was still restricted by the rf system. The beam energy of 5.2 GeV was achieved in Dec. 1983 with use of two disc and washer type cavities fed by a 500 MHz klystron of 1 MW design power. Total length and shunt impedance of the cavities are about 10 m and 250 MΩ, respectively. The maximum rf power which the klystron can deliver remains to be about 250 kW due to various technical problems.

Maximum current
A single bunch beam current up to 66 mA could be accumulated at 2.5 GeV. What limited the current was a large pressure increase in the cavities which tripped the rf power. As the average vacuum deteriorated considerably due to the effect of the synchrotron light generated by the beam, the single beam lifetime was still very short, about half an hour.

Lattice parameters
After surveying several tune parameters for better injection efficiency and beam stability, the horizontal and vertical betatron tune were chosen to be ν_x = 10.17 and ν_y = 10.24. A very good agreement between the measured tunes and the predicted ones proved that the absolute strengths of the lattice magnet system were well calibrated.

Closed orbit distortions
Displacements of the closed orbit from the central axis of the lattice quadrupole magnets were measured by use of 83 electrostatic type position monitors disposed around the ring. Average displacements obtained were about 4 mm and 1.6 mm in the horizontal and vertical direction, respectively, and consistent

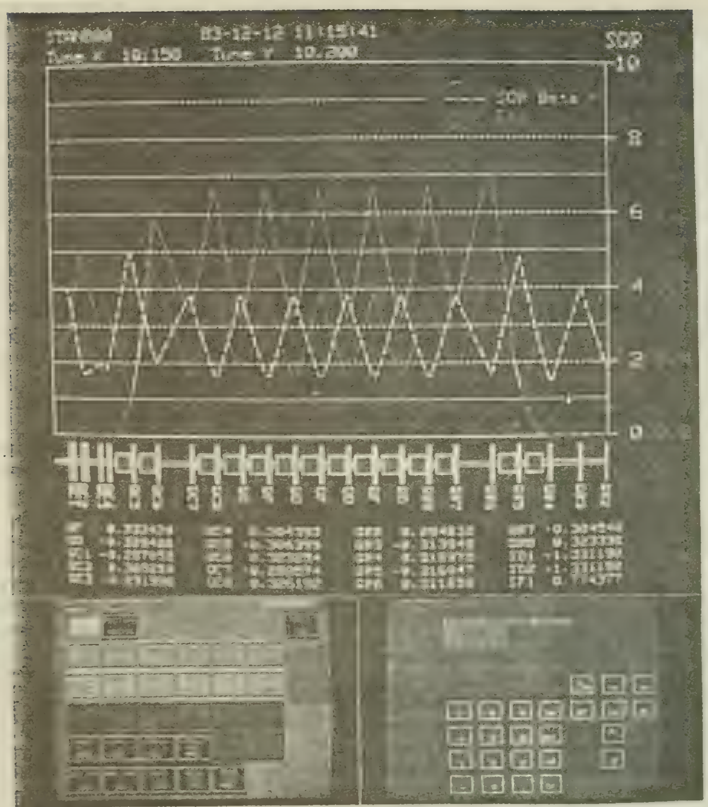


Fig. 3. An example of the TRISTAN control panel. A graphic display showing betatron functions (β_x, β_y) and dispersion function (η_x), and touch panels to execute the control functions.

with what were expected from the alignment errors of the lattice magnets. Those orbit errors were corrected by 66 horizontal and 44 vertical steering magnets. A typical example of the corrected closed orbit distortions is shown in Fig. 4. It is seen that the average distortions are reduced to a few tenth of a millimeter.

Beam instabilities
Several types of beam instabilities were observed, and have been under the detailed studies. A strong head-tail instability of the lowest order was encountered at the beam current of a few tenths of a milliampere. This could easily be cured by making the chromaticity positive with use of a sextupole correction magnet system. Another transverse and longitudinal instabilities were found to be avoidable by adjusting the rf accelerating voltage and the cavity tuning.

At the end of the AR operation in this fiscal year, a

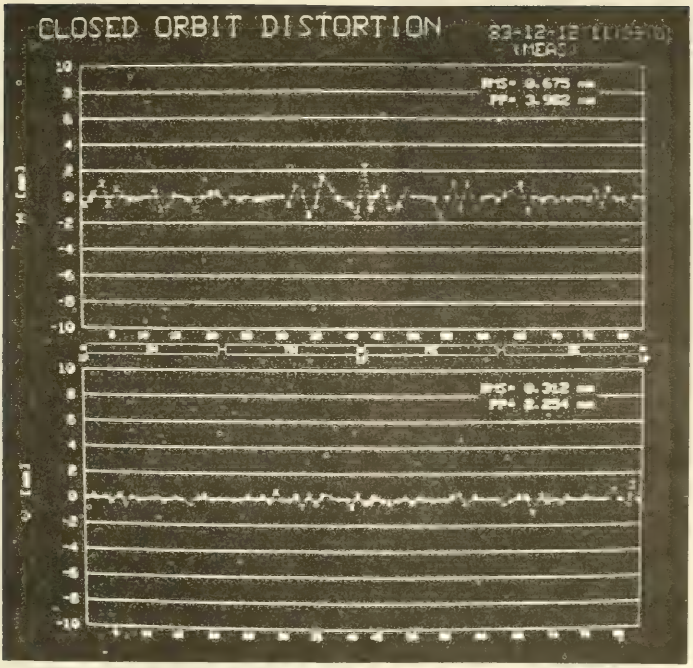


Fig. 4. An example of the closed orbit distortions in AR, which remain after corrected by use of the steering magnets.

three-cell 500 MHz superconducting cavity was installed in the ring and submitted to various kinds of operational tests without beams. Then, it is planned to accelerate beam with this cavity at the beginning of the next series of the AR operation starting from May 1984.

Main Ring

Based on the very successful results in AR, the construction of accelerator elements of the TRISTAN Main Ring, MR, is duly in progress.

Most of the MR main bending and quadrupole magnets have been fabricated and delivered to KEK. After being submitted to the magnetic field measurement, the magnets are stocked in an assembly hall as shown in Fig. 5. Figure 6 illustrates geometrical apertures of the magnets together with cross sections of the vacuum tubes. Installation of the magnets in the MR tunnel, Fig. 7, is scheduled to start in September 1984.

The present bending magnet system is designed to be operative at beam energies as high as 40 GeV. While the working energy of the quadrupole magnet system will be limited at about 35 GeV. To go beyond this, it might be needed to replace some of the quadrupole magnets with superconducting ones.

As already known, the highest attainable beam energy of MR is determined by an available accelerating

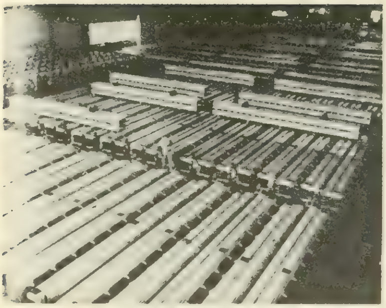


Fig. 5. TRISTAN-MR main magnets which are ready for installation in the tunnel.

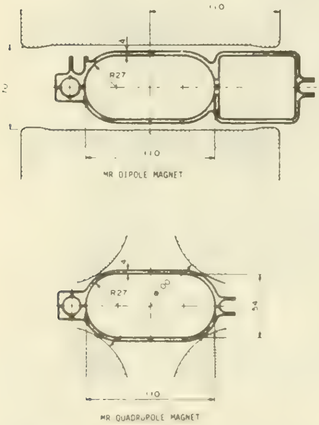


Fig. 6. Geometrical apertures of the TRISTAN-MR bending and quadrupole magnet. Also shown are cross-sections of the vacuum tubes.

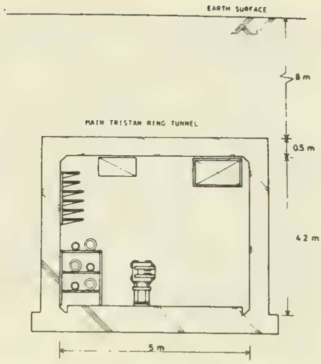


Fig. 7. Cross-section of the TRISTAN-MR tunnel in the arc.

rf voltage. For instance, a peak rf voltage of about 383 MV will be required at 30 GeV. In the case of the conventional room temperature cavity, the cavity wall loss is a significant part of the rf power consumption. Then, a cavity of higher shunt impedance is desirable for generating larger accelerating voltage within a limited power. However, it should be noted that a large impedance also implies a strong coupling between the beam and cavity, and may cause a serious beam instability. After extensive development works, we have decided to adopt the alternating periodic structure, APS, for the MR accelerating cavity. APS is a confluent type, in which the TM_{01} mode has a finite group velocity at the accelerating frequency, and has wide mode separations compared with ordinary slot-coupled cavities. One of the most desirable of the present APS is that it has a perfect axial symmetric structure and is expected to behave in accordance with computer calculations. A unit of the MR rf cavity is a 9-cell APS, the cell unit of which has dimensions as shown in Fig. 8. The shunt impedance of the cavity thus designed is calculated to be 28.2 MΩ/m with use of the computer code SUPERFISH, and that of the practical one is expected to be not less than 80 % of this figure. The cavity body will be made of a low carbon steel. A copper layer of about 0.2 mm thick is electroplated on the inner surface in a pyrophosphrous acid bath. Figure 9 shows a picture of the 9-cell APS test cavity under fabrication.

In parallel with the conventional room temperature cavity, extensive works are going on to develop a 500 MHz superconducting cavity for practical use in TRISTAN. As described below, recently a three cell cavity has been fabricated to make an acceleration experiment in AR. The preliminary test of the cavity at

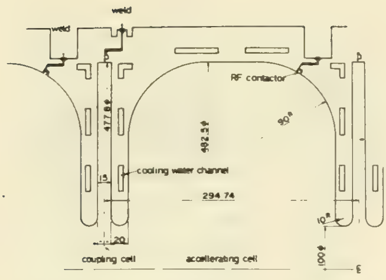


Fig. 8. Unit cell structure of the TRISTAN APS type rf cavity.

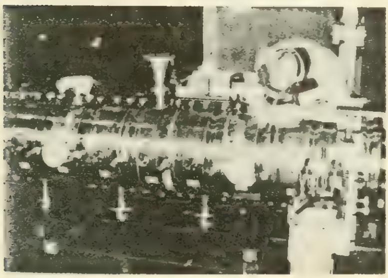


Fig. 9. A 9-cell APS test cavity under fabrication.

4.2 K in a vertical cryostat has proved that an attainable accelerating field might exceed 5 MV/m, and has strongly encouraged a possible extension of the MR beam energy to considerably higher values than the originally designed.

In building the MR rf system, we are going to proceed on the following plan. As the first stage, we will fill three long rf sections, Fuji, Oho, and Tsukuba side, with 104 units of the room temperature 9-cell APS cavities, and the remaining one, Nikko side, with 40 units of the 5-cell superconducting cavities. The construction of the room temperature cavity system is scheduled to take about two and a half years, and it will take at least one more year to complete the superconducting cavity system. The highest MR beam energy attainable with this first stage rf system is estimated to be about 33 GeV, provided that the 9-cell APS cavity unit is operated at the largest available input rf power of 150 kW, corresponding to a field strength of 1.1 MV/m, and the 5-cell superconducting cavity unit produces a field strength of 4.3 MV/m at the highest. To reach higher beam energies, we intend to replace the room temperature cavities with the superconducting ones successively in the later stage.

As shown in Fig. 10, a room temperature cavity composed of 9-cell APS cavity units is installed in an rf straight section between the lattice quadrupole magnets. An output of a 1 MW klystron will be delivered to four 9-cell APS cavity units, after being fed through a circulator and equally divided into four by magic tees. Figure 11 shows construction work for one of the MR long straight sections to install rf cavities.

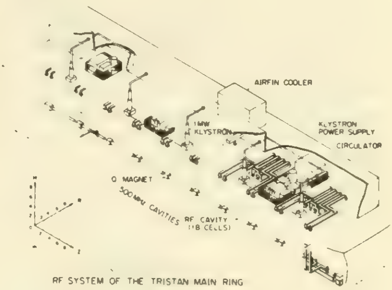


Fig. 10. Setup of the TRISTAN-MR rf system for the APS cavities.

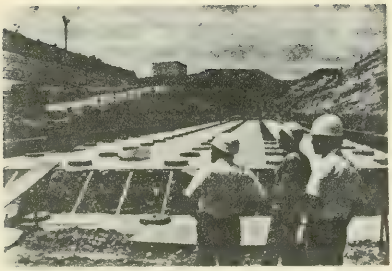


Fig. 11. Construction work for one of the MR long straight sections to install rf cavities.

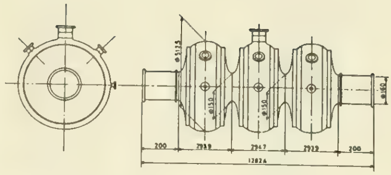


Fig. 12. Three-cell 508 MHz structure.

Development of Superconducting Cavities

Since 1979 we have been working on 500 MHz niobium single cavities. Typical results were Q_0 at low field of 4.2×10^9 and accelerating field gradient of 6.5 MV/m at 4.2 K. In FY 1983, a three-cell 508 MHz structure has been built and pretested. The structure has an input rf coupler ports on the center cell, two higher mode coupler ports on each cell as shown in Fig. 12. Fabrication and surface treatment techniques were similar to those for the previous single cells. Prior to assemble the three-cell structure, each cell was tested as the single cell with beam tube. Accelerating gradient has been improved by successive grinding and surface treatment after each test of the single cell. After assembled to the three-cell structure, it has been tested at first in a vertical cryostat with all coupler ports blanked off. Q_0 at low field of 1.3×10^9 and accelerating gradient of $E_{acc} > 5.2$ MV/m were obtained at 4.2 K. Maximum E_{acc} was limited by available rf power.

The three-cell structure has been assembled with the input coupler, three higher mode couplers and a frequency tuning mechanism in a horizontal cryostat

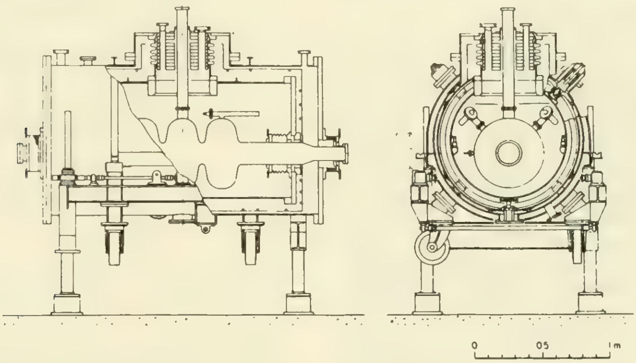


Fig. 13. The cross-sectional view of the cryostat.

and installed in the TRISTAN accumulation tunnel to do the beam test. Figure 13 shows the cross-sectional view of the cryostat.

Superconducting Insertion Quadrupole Magnet for the TRISTAN Main Ring

In order to increase the luminosity for e^+e^- collisions in the TRISTAN Main Ring, superconducting low β insertion quadrupole magnet was designed. The main parameters of the quadrupoles are given in Table 2 and the cross-sectional structure is shown in Fig. 14.

Due to the high field gradient and the large coil innner diameter (I.D.), the required ampere-turns per pole are very large. On the other hand, the coil outer diameter (O.D.) is restricted by the requirements of the colliding beam detectors. These situations imply that the coil current density must be as high as possible.

In FY 1983, an excellent high current density NbTi/Cu superconducting cable was developed for these quadrupoles. The superconductor to copper ratio of the cable is 1 to 1.1. Twenty-seven NbTi/Cu strands are compacted into a keystoned Rutherford cable. The average current density in the cable is 609 A/mm^2 at 6 T and 4.2 K.

The construction of a prototype quadrupole magnet will start in FY 1984.

Table 2. Main Parameters of Superconducting Insertion Quadrupole Magnet

Field gradient	70 T/m
Coil current	3480 A
Magnetic length	1 m
Turns per pole	127
Coil I.D.	140 mm
Coil O.D.	217 mm
Stored energy	75 kJ

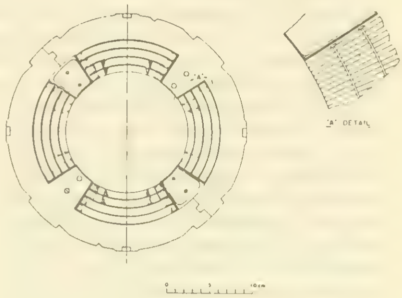


Fig. 14. Cross-sectional structure of insertion quadrupole magnet.

PHYSICS

At the end of March, 1983, the laboratory gave full approval to the VENUS(TE-001) and TOPAZ(TE-002) proposals, following the recommendation of TPAC (the TRISTAN physics program advisory committee). With this authorization, the VENUS and TOPAZ collaborations have been working with enthusiastic efforts to construct their detectors and to make them ready for operation beginning from the first day (t = 0) of TRISTAN e^+e^- collider operation.

In general, construction work for the TRISTAN experimental halls (FUJI, TSUKUBA, OHO and NIKKO) as well as for VENUS and TOPAZ detector components has been carried out quite smoothly In the March TPAC meeting, in reviewing the recent progress in the CERN S$\bar{p}$pS collider experiments, in

particular the discovery of the long awaited $W^{\pm}$ and Z^0 bosons, it was suggested that preparations should be made for unexpected physics results. Among other things, it was emphasized that the TRISTAN energy should be as high as possible, with additional efforts to employ superconducting cavities in the Main Ring. Low beta superconducting quads in the interaction regions were also strongly recommended from the point of view of improving luminosities. This may add even wider capability to the physics potential of TRISTAN, as we discussed in the 1982 annual report. Extensive efforts have been underway for developing these cryogenic facilities.

Following the recommendation made in a tentative approval at the March TPAC meeting, the TPAC met again in November, 1983 in order to review the full proposals of AMY and HRS, both of which are collaborations between United States and Japanese groups, submitted to the laboratory after further efforts in refining their experimental plans and in strengthening their physics capabilities. The HRS collaboration with its currently-working detector featuring a very high resolution spectrometer, aimed to be the first t = 0 detector in the TRISTAN collider, in order to explore toponium physics. The AMY collaboration, proposing a new detector with a very interesting concept for making a rather compact but very capable detector, had as experimental objectives the study of various toponium physics as well as interference phenomena around the hitherto totally unexplored energy region $50 < \sqrt{s} < 70$ GeV, just below the threshold of Z^0 production. Following the TPAC recommendation to the Director General, the Laboratory gave the AMY collaboration full approval, but deferred a decision for the HRS detector. Having been fully approved by the laboratory and having received confirmation of DOE support in the United States, the AMY (TE-003) collaboration started work to construct their detector with hopes to make it ready for operation at t = 0.

The November TPAC meeting recognized that the construction of various components for the VENUS and TOPAZ detectors has made excellent progress. Recognizing this success in the detector construction work, the TPAC concured with the Laboratory Directorate that both collaborations should continue efforts to construct these two detectors in parallel, without any specific priority being assigned. Although there are still problems to be solved, the construction work on these TOPAZ and VENUS detectors is going well, as is described in subsequent sections of this report.

Fig. 15. The TPAC meeting in Nov. 1983.

Since detector components, such as lead glass Cerenkov counters for electromagnetic shower calorimeters in the TOPAZ and VENUS detectors, are in full production, an extensive calibration program is an immediate order of business. With successful operation of the electron beam at the Accumulation Ring, which came into operation in November, 1983, preparation of two bremsstrahlung beam lines from internal targets was made for producing electron/positron beams for various detector calibration tests. The beam lines, called IT-1 and IT-4, are now completed and ready for tests. Another test beam line, producing electrons and hadrons for TRISTAN detectors, was also constructed, in the counter experimental hall at the 12 GeV proton synchrotron beam area.

Construction work on FUJI, TSUKUBA, OHO and NIKKO experimental halls on the Main Ring, has also been going quite smoothly. The FUJI hall, which accommodates the VENUS detector, will be the first to be completed, in the middle of FY-1984, followed by TSUKUBA for the TOPAZ detector, only 2 ~ 3 months thereafter. The construction of OHO and NIKKO is also underway in order to be ready at least a year or so in advance of the first day for beam collision. The OHO hall is to accommodate the AMY detector and is the smallest hall among the four. In addition to the two experimental halls at the Accumulation Ring, which are being used for detector compo-

nent tests, a large assembly hall was completed. This hall is being used for assembling and testing various detector components.

One of the most important support activities for TRISTAN experiments is the On-Line Data Acquisition and Electronics System Group. As we discussed in the 1982 annual report, procurement of two VAX-11/780 and one VAX-11/750 systems, was made, and a wide variety of activities has been carried out for on-line data handling for TRISTAN experiments. Extensive FASTBUS and front-end electronics development has also been underway. These activities are outlined in a separate part of this report, under Physics Department, in the section on instrumentation in counter experiments.

In addition to the on-line data acquisition system, it is clear that a large and capable off-line computing facility is an absolute necessity. This will enable experimenters to carry out off-line analysis on the large amount of data produced each day at the TRISTAN experiments. A preparatory working group has been established in order to make the necessary specifications for this off-line data analysis facility. Plans for procurement of a new off-line computing facility, that is to be used solely for TRISTAN physics analysis, is in progress. This TRISTAN off-line computing system, which is tentatively called the "B system", relative to the "A system" at the KEK central computer for all common users at KEK, will be installed sometime in fiscal year 1985.

Development and maintenance of cryogenic facilities, such as He refrigerators and associated systems, will become an essential part of support activities for the TRISTAN experiments. With three superconducting magnets to be operated in the three (VENUS, TOPAZ and AMY) detectors at the TRISTAN Main Ring, efforts have been taken to organize and extend the capabilities of the Cryogenic Operations Group in the Physics Department. Construction work on He refrigerators for the VENUS and the TOPAZ detectors is now underway by this group, with the participation of both experimental groups. A conceptual design for the cryogenic system for the AMY 3 Tesla superconducting magnet is also in progress. With these three cryogenic facilities on the Main Ring, a concept for centralized operation of these three facilities has been developed. A centralized control system for these cryogenic facilities is now partially under construction.

In conclusion, the construction work on TRISTAN experimental facilities has become very wide and diverse in every sense, and has shown substantial progress and developed considerable momentum during fiscal year of 1983. It is hoped that this activity, with its momentum, will continue to be as strong in the forthcoming years as it has been in the past.

TRISTAN Experimental Area

There are four experimental halls FUJI, NIKKO, TSUKUBA and OHO to be built on the TRISTAN Main Ring, as is shown in Fig. 16. During fiscal year 1983, extensive construction work on the FUJI and the TSUKUBA experimental halls has been carried out. These two halls are of almost the same design. The FUJI hall, where the VENUS detector will be installed, is scheduled to be completed in October, 1984, although a temporary air conditioning system will be used at the beginning. The TSUKUBA hall, which will accommodate the TOPAZ detector, will follow the FUJI hall about two months later. Construction of the NIKKO and OHO halls was started in February and April 1984, respectively. The OHO hall is to accommodate the AMY detector.

Figure 17(a) shows a floor plan of the FUJI hall at its bottom level (B4). Cryogenics for all experimental halls will be controlled at the central control room in the FUJI hall (B2), which is shown in Fig. 17(b). Figures 18(a), 18(b) and 18(c) show elevation views from each side of the hall. The floor of the hall has a width of 27 m along the $e^+ e^-$ beams and is 53 m long. It is composed of a beam collision area and an assembly area which are separated by radiation shield walls. The beam level is 5.7 m off the hall floor, which is 16.3 m below ground level. A compressor room for the cryogenic system of the detector, gas storage yards for the cryogenics and chamber gases, and a yard for reservoir tanks of liquid nitrogen and other fluids will be prepared outside the hall.

The hall is provided with a drop hatch that is to be used for bringing heavy components of the detector into the hall. The hatch room, which is, equipped with a 50 ton crane, is 9.5 m wide and 7.5 m long. The hall has a 70 ton crane with auxiliary hooks of 15 tons and 4.5 tons, which cover both the collision and the

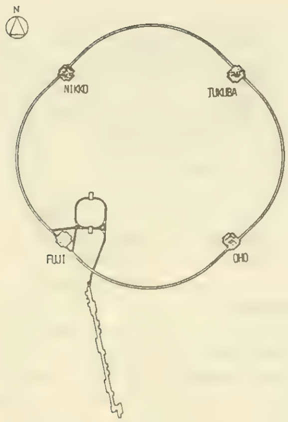


Fig. 16. Locations of the four experimental halls at each straight section of the TRISTAN Main Ring. The halls are named after two mountains, a temple and a town. Mounts Fuji and Tsukuba, the temple at Nikko and the town of Oho are aligned geographically in the background of the respective hall when viewed from the center of the main ring.

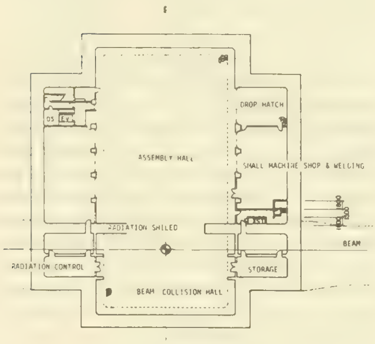


Fig. 17(a). A floor plan of the Fuji hall at the assembly and the collision areas level (B4). Rooms at the sides of the hall are used for a small machine shop, welding room and other shops. A truck of 50 tons capacity will connect the drop hatch and the assembly hall.

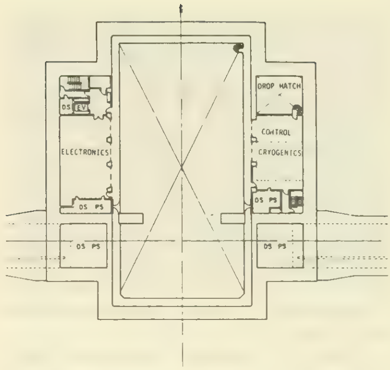


Fig. 17(b). A floor plan of the side gallery of the Fuji hall at the first basement (B1). On one side, a central control room for the cryogenic system will be installed and on the other side, a room for electronic work is planned.

assembly areas. A speed regulator enables the crane hook to go up-down at any speed between 7.0 and 0.35 m/min. The control accuracy of crane operation is expected to be of the order of 0.5 mm with full load.

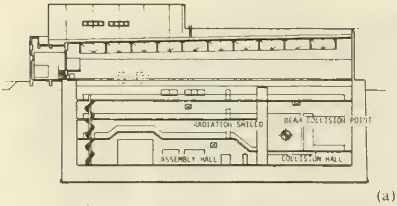
The hall floors are designed to support detector loads as large as 3,000 tons. The floor is flat to ± 1 mm over 20 m along the rail structures which will be used for moving the detectors between the collision and the assembly areas.

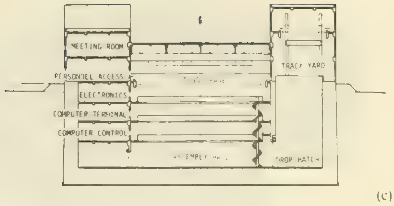
Floor sizes of the NIKKO and the OHO halls are smaller than those of the FUJI and the TSUKUBA halls, which accommodate rather large general purpose detectors; the VENUS and TOPAZ detectors. The NIKKO and OHO halls will be completed in the summer of 1985.

Two experimental halls in the Accumulation Ring were also completed in FY 1983, and can be used for possible future experiments.

An assembly hall, which is used for assembly and testing of various accelerator and detector components, was completed in October 1983. The hall has a floor size of 120 m long by 50 m wide.

Photographs, Fig. 19 and Fig. 20, show the recent status of construction work on the experimental halls.





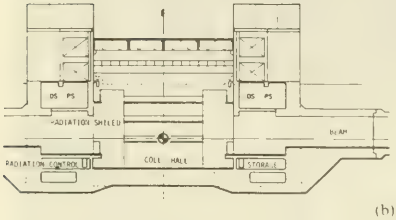


Fig. 18. Side views from each side of the hall. a) Side view along the beams. The beam collision point is shown by a cross. b) Collision area viewed perpendicular to the beams. Accelerator tunnels and radiation shield walls are shown. The beam collision point is indicated by a cross. c) Assembly hall and its side rooms. The assembly hall and six-story side galleries (four stories under ground and two stories above ground) are shown. A computer and terminals for the data acquisition system are installed at B3 and B2.

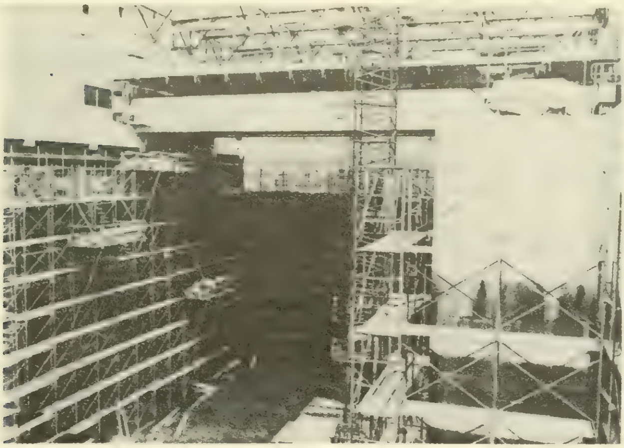


Fig. 19. Inside view of the Fuji hall. Radiation shield wall (at right), walk ways (at left) and 70-ton bridge crane are seen. The beam collision point is at the center of photograph (5.7 m above the floor). (April 1984)

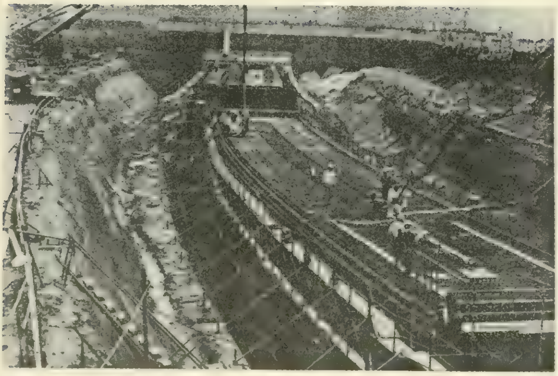


Fig. 20. The accelerator tunnel at the north area looking at the straight section and in the background an external wall of the Tsukuba hall. (April 1984)

VENUS Collaboration

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College of Liberal Arts, Kobe University
College of Applied Medical Science, Kobe University
Physics Department, Kyoto University
Faculty of Engineering, Kyushu University
Physics Department, Osaka University
Physics Department, Rikkyo University
Physics Department, Tohoku University
Faculty of Technology, Tohoku Gakuin University
Faculty of Engineering, Tokyo University of Agriculture and Technology
Physics Department, Tokyo Metropolitan University
Institute of Applied Physics, University of Tsukuba
Institute of Physics, University of Tsukuba
Wakayama Medical College

FY 1983 was a year in which fabrication of major detector elements for VENUS, such as the superconducting solenoid, return yokes, the central drift chamber and the barrel calorimeter, was started using the final designs developed after a year of R & D effort. Construction has progressed rather smoothly. Fabrication of superconducting wire and some parts of the cryostat for the solenoid have been completed and a frame for the central drift chamber was delivered to KEK for stringging wires. Several hundred subassemblies for the lead glass Cerenkov counter in the barrel calorimeter have also arrived at KEK to be tested at the IT-4 test beam facility. Figure 21 shows a perspective view of the VENUS detector. In the following, progress in construction of detector elements will be described.

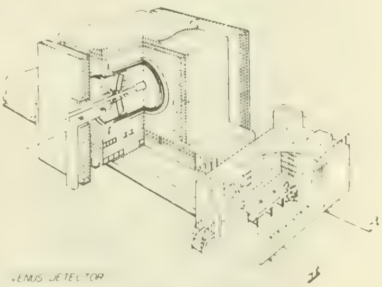

Fig. 21. A perspective view of the VENUS detector.

Superconducting Solenoid and its Cooling System

Based on the experience gained during construction of the R & D solenoid and cryostat, the final design

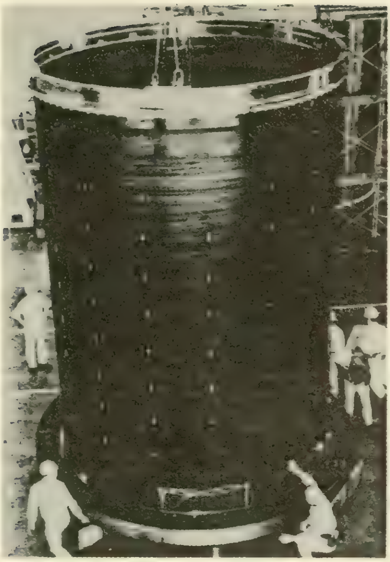

Fig. 22. A view of the CFRP cryostat which will be used for the superconducting solenoid magnet.

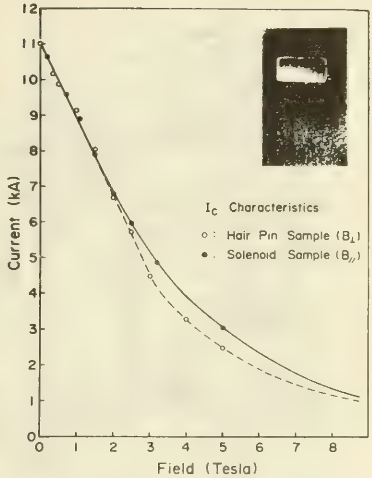

Fig. 23. Critical current (Ic) characteristics and a cross section view of the superconducting cable. The operation point will be 4100 A at 0.75 Tesla.

for the VENUS magnet was worked out. It uses Carbon Fiber Reinforced Plastic (CFRP) for the outer wall of the cryostat. The use of CFRP, instead of aluminum, reduces the radiation thickness of the solenoid from about 0.65 rad. length to 0.55. Figure 22 shows the CFRP cylinder which was fabricated by Mitsubishi Electric Co.

An aluminum-stabilized superconducting wire was developed and the fabrication of about 10 Km of the wire has now been successfully completed. Using a short sample, a current of about 10000 A at 1 Tesla can be supplied with this wire as shown in Fig. 23; a value that is far beyond the value needed for normal operation, namely 4100 A at 0.75 Tesla. In Fig. 23, a cross section view of the wire is also shown. The magnet yoke and mounting frame, shown in Fig. 24, were fabricated by Kawasaki Heavy Industries Ltd. They will be installed at KEK in the fall of 1984.

A refrigerator which can supply 150 ℓ of liquid helium per hour at 4.4 K was constructed by Teisan K.K.. Construction of a liquid nitrogen supply and helium and nitrogen gas compressors will complete the cooling system for the VENUS solenoid.

Central Drift Chamber

The end plates for the central drift chamber were brought into the former bubble chamber building and the stringing of wires was carried out in a dust-free room. As shown in Fig. 25 about 40% of the total 28316 wires were already strung, by the end of the FY 1983. This chamber uses CFRP for the inner and outer walls. The CFRP was fabricated and stress tests with the two end plates were successfully carried out by Kawasaki Heavy Industries Ltd.

The prototyping of the preamplifier was finished. It was used in a performance study of a prototype chamber in a magnetic field. Prototype TDC modules on FASTBUS boards were designed by the KEK elec-

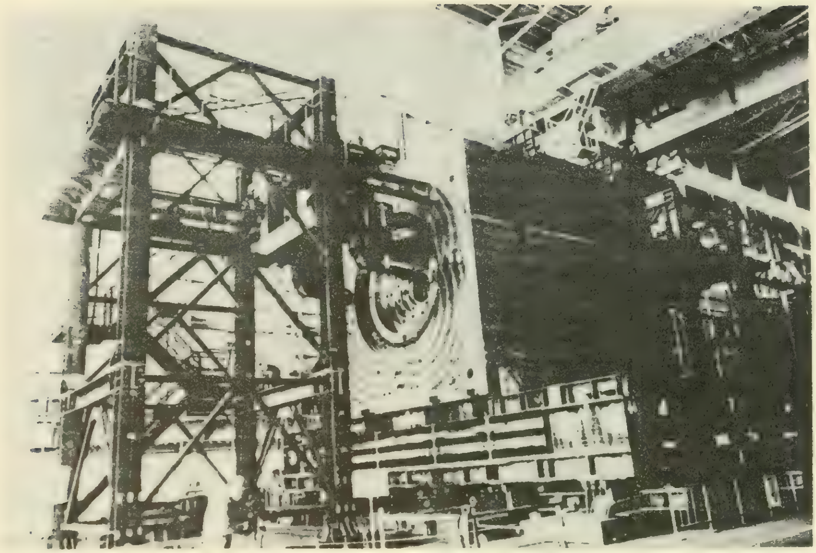

Fig. 24. A view of the return yoke and mounting frame.

tronics group.

Barrel Calorimeter

During FY 1983, great progress was made in the mass production of the lead glass Cerenkov counters which will be used for the barrel calorimter. Out of 5160 lead glass counters needed for the calorimeter, about 800 were fabricated using lead glass DF6 from Nippon Kogaku K.K. and with H1911 photomultipliers from Hamamatsu Photonics K.K.

The effects of different light-guide materials on the performance of the lead glass counter were examined, using light-guides made of acrylite plastic, BK-7, and DF6 glass. The acrylite light-guide, with a cut-off wavelength of 420 nm, showed the best hadron suppression factor among the light-guides given above, as shown in Fig. 26. A monitoring system using a Xe-lamp and quartz fibers was made for the tests. The reproducibility of the pulse response of the monitoring system at the connector was found to be better than 99%. Using the monitor system, the long term stability of the photomultipliers was tested; the criterion being that the PMT's should have a stability of better than 2% over a period of 10 days.

The supporting frames for the lead glass counters were fabricated at the KEK workshop and by Mitsubishi Heavy Industries Ltd. These support frames have been used for gain calibration of the lead glass using the electron beam at beam line IT4 of the Accumulation Ring.

Endcap Calorimeter

A 3 × 3 array of prototype liquid argon shower counters was built and their performance was studied. Figure 27 shows an energy deposit spectrum for 2 GeV/c electrons. The energy resolution was found to be about $10\%/\sqrt{E}$. The hadron suppression factor was about 1/300 for a known particle momentum, after a longitudinal and lateral cut of the spread of the shower data was made.

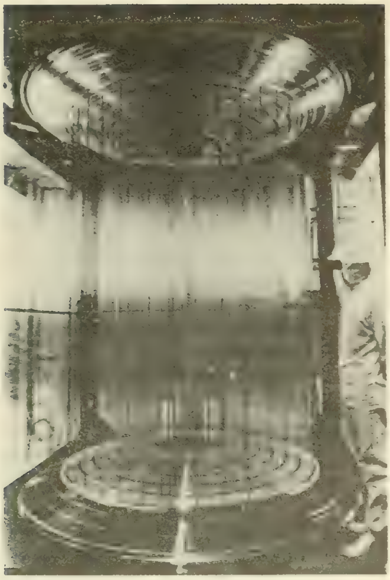

Fig. 25. A view of wire stringing for the central drift chamber. There will be 28316 wires.

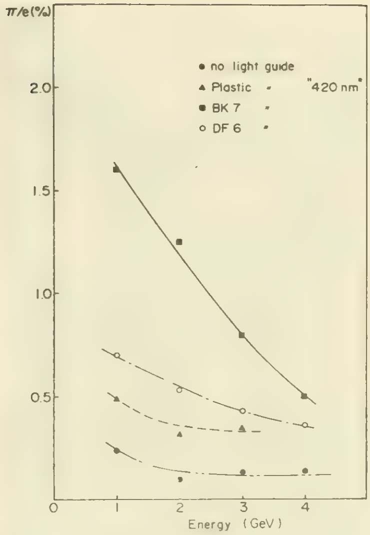

Fig. 26. Hadron suppression factors for different light guides tested for use in the barrel calorimeter.

A detailed design study was made in order to finalize the liquid argon shower counter system. A response analysis for mechanical vibration was made to make sure that the system will remain safe during possible earthquakes.

Other Components

Performance studies of prototype TOF counters and related R & D work has been performed in FY 1983. To select the best scintillators and phototubes and also to find the optimal scintillator dimensions and counter arrangements, time resolutions of several prototype TOF counters were measured. As shwon in Fig. 28 the resolution is better than 200 psec for a counter which consists of 4 m long and 4 cm thick scintillator and 1 m long light guides at both ends.

Prototypes of the inner chamber, a PWC, and the muon chamber drift tubes, were constructed. Special care was taken to select gases for stable operation.

Prototypes of the luminosity counter and the transition radiation detector were also made.

Data Acquisition System and Off-line Analysis

Data transfer from FASTBUS to the VAX computer through the VAX-FPI (VAX-FASTBUS Processor Interface) was successfully tested. Several FASTBUS modules, a Simplex Segment Interconnect, an Ancillary Logic and a Master module (68K-FPI) were developed. Design and construction of a first level trigger module and a track finder module were carried out on a FASTBUS board using 4K RAMs.

The event generation programs and event simulation programs for VENUS were written and a monitoring system for the VENUS detector components was discussed.

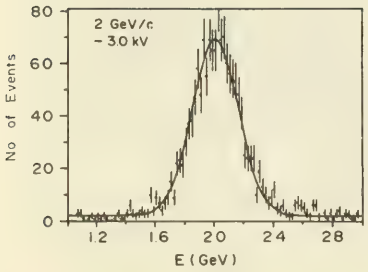

Fig. 27. Energy deposit spectrum for a 3 × 3 array of prototype liq. Argon counters for 2 GeV electrons. This measurement shows an energy resolution of $10\%/\sqrt{E}$.

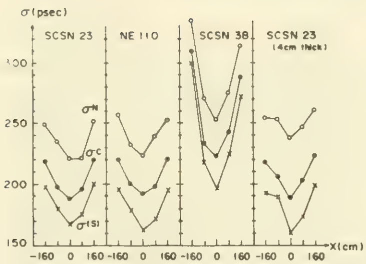

Fig. 28. Time resolutions for several scintillation counters with Hamamatsu R1828 phototubes, for the TOF counters. In the figure, σ^N stands for the uncorrected time resolution, σ^C is the pulse height corrected time resolution and $\sigma(S)$ means the time resolution after the start signal fluctuations have been subtracted.

Conclusion

Construction of most of the urgent components, the central drift chamber, the barrel calorimeter and the superconducting solenoid, is scheduled to continue into FY 1984. Although delayed by one year for financial reasons, the construction of other elements will start in FY 1984. In spite of the very tight momentary situation, major detector elements are expected to be ready for the experiment from the first day, T = 0, of TRISTAN operation namely, in the fall 1986.

TOPAZ Collaboration

KEK, National Laboratory for High Energy Physics
Dept. of Phys., University of Tokyo
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Dept. of Appl. Phys., Tokyo Univ. of Agriculture and Technology
Dept. of Phys., Nagoya University
Dept. of Phys., Nara Women's University
Dept. of Phys., Osaka City University

. Following R & D work carried out in the last year, actual construction of major detector components was started in FY 1983. They include the superconducting magnet and its cryogenic system, the barrel calorimeter and the pressure vessel of the Time Projection Chamber (TPC) as well as the spectrometer support structure. Prototypes have been tested for the inner drift chamber, the time-of-flight counter, the barrel and the end cap drift chamber, the end cap calorimeter, and the muon drift chamber. Final designs have thus been obtained for most of these, to be ready for mass production in FY 1984. Figure 29 shows a perspective view of the TOPAZ detector.

Active software work has also been conducted. The major effort in this area was to prepare a full-scale detector simulation program and our own data banking system.

Central Tracking Chambers

The inner drift chamber consists of 5 cathode cylinders of paper honeycomb and 10 layers of small drift cells. In order to simplify chamber fabrication, the cathode strip readout was replaced with a delay line. Zig-zag delay lines are printed on 8 cathode surfaces facing the drift cells. A series of studies on the drift

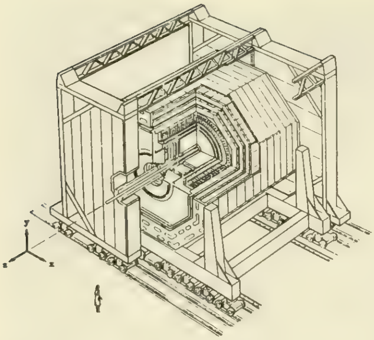


Fig. 29. A perspective view of the TOPAZ detector.

cell configuration was therefore followed by extensive prototype work on the optimization of delay line parameters and the development of readout electronics. Spatial resolutions observed with a test beam are 110 μ by the drift method and 4 mm on the delay lines (35 Ω impedance and 5.9 ns/cm speed). Figure 30 shows two cathode cylinders equipped with the delay lines. Aluminum end plates for the chamber have been drilled.

The decision was made to construct the TPC pressure vessel with Glass-Fiber-Reinforced Plastic (GFRP) since its electrical and mechanical properties have been substantially improved by vacuum impregnation techniques. For example, a volume resistivity of 6×10^{15} Ω-cm (at 1 min.) and a Young's modulus of 3600 Kg/mm^2 are obtained. Both outer and inner cylinders have been constructed with GFRP as shown in Fig. 31.

High voltage insulation problems are eased by using coarse field shaping on the inner surfaces of the cylinders. Fine shaping of the drift field is then performed with conductive fins, regularly spaced on GFRP boards (Fig. 32). Equi-potential rings to produce a uniform electric field of 380 V/cm are formed by 8 such boards attached to each cylinder.

A big effort was undertaken to develop TPC sectors. It included the fabrication of a 1/5 portion to verify its intricate design, including production of large, high-quality G-10 boards with fine glass fibers

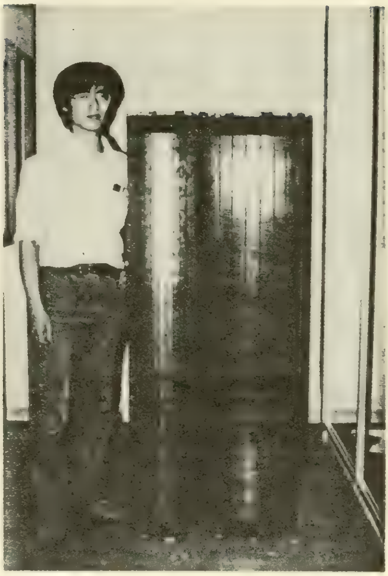


Fig. 30. Honeycomb cathode cylinders for the TOPAZ inner drift chamber. Zig-zag delay lines are printed on Kapton sheets for the second coordinate readout.

and precision etching of a full cathode pad pattern. Having confirmed the technical feasibility of the key parts, actual production is planned to start in 1984.

For the TPC readout electronics, FY 1983 was a period for design and prototype work. Significant quantities of preamplifiers and CCD digitizers were produced. They will be soon tested to prepare for mass production. Figure 33 shows the CCD performance; a test pulse was sampled at 10 MHz and the base line shift due to leakage (typically 0.06 %/ms of full dynamic range) was subtracted.

g. 31. Outer GFRP cylinder for the TOPAZ-TPC pressure vessel. Rings of thin copper tube are glued at equal spacings on the inner surface to ease electrical insulation problems.

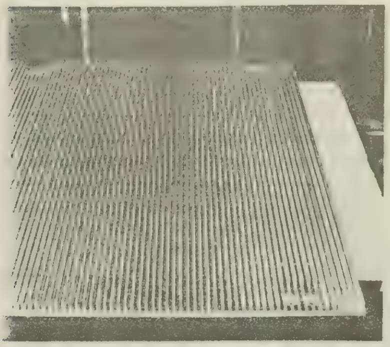


Fig. 32. Fin-type field cage for the TOPAZ-TPC. The conductive fins are regularly spaced on a GFRP board to make the drift field very uniform and also to screen the drift volume from any local charge on the board.

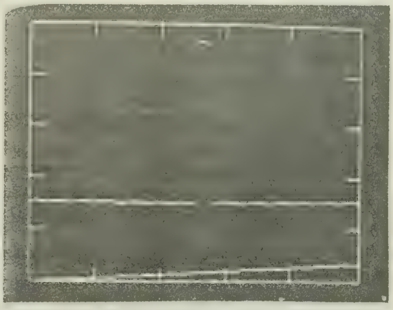


Fig. 33. A test of the CCD to be used in the TOPAZ-TPC digitizer. A test pulse was sampled at 10 MHz and then digitized with the inclined base line subtracted.

Outer Drift Chambers

Both the barrel and the end-cap drift chamber, covering the entrance to the calorimeters, are single-wire conductive plastic tube counters operated in the limited streamer mode. Basic performance was examined for individual counters and then 8 counter-planes were exposed to a beam. The average position resolution was 110 μm in each counter and this performance was maintained for an instantaneous rate of up to 5 KHz per cm of wire.

The muon detector consists of a large number of single-wire drift counters made of extruded Al tubes, each 5 × 10 cm^2 in cross section and 6 m in length. Various tests were carried out with full-scale counters to optimize operating parameters and to check performance stability against any changes in environment. Position resolution measured for cosmic rays with 6 layers of counters was 0.7 mm without any correction for nonlinearities. Charge division was also tested as an optional readout method and a resolution of 1.2 cm was achieved with 50 μm nichrome anode wires (3 kΩ in total resistivity).

Calorimeters

Extensive tests were performed on lead glass and photomultiplier until April 1983 and following this, the barrel calorimeter went into mass production. A 3-inch proximity focussing photomultiplier is attached via a 6 cm long lead-glass light pipe to a 34 cm long (20 radiation length) SF6W lead glass radiator. This allows a μ-metal shield to be used against the leakage field of the superconducting coil and also minimizes the light intensity generated by noninteracting charged pions. The mechanical structure at the rear end of each counter accommodates an optical fiber which delivers standard light pulses from a common Xenon lamp for monitoring the gains of photomultipliers. 720 counters purchased in FY 1983 are being assembled into support modules as shown in Fig. 34. All the counters are to be calibrated with a secondary electron beam from the Accumulation Ring, and test facilities have been prepared.

The end-cap calorimeter is a sandwich of proportional counters and lead sheets. A prototype calorimeter was constructed with conductive-plastic-tube counters 1.0 × 1.5 cm^2 each in cross section. The signal was taken from cathode pads of 9 × 9 cm^2 area each, with the total depth (18 radiation length) electrically subdivided into 3 sections. The energy resolution observed in a test beam was 21 $\%/\sqrt{E}$, the spatial resolution 6 mm, and the pion suppression factor 1000 at 4 GeV when 95% of electron signals were accepted. An improved mechanical design is underway, with the basic structure unaltered.

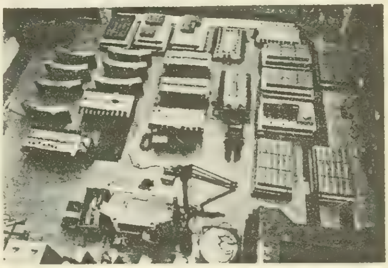


Fig. 34. Mass-produced TOPAZ lead-glass counters and their support modules. The counters are being assembled into the support in units of 60 counters.

Superconducting Magnet

Having gained confidence in the construction techniques through various tests and practice trials in 1982, the magnet construction came into full swing. The Al-stabilized Nb-Ti/Cu superconductor was successfully wound by the internal winding method. This coil, 288 cm in inner diameter and 510 cm in length, passed mechanical as well as electrical tests. It was then encased in the cryostat structure for cool-down tests scheduled in 1984. Figure 35 shows the outer cylinder into which the coil was wound. It should be mentioned here that, immediately after the report on the PEP-4 magnet trouble, an improved and extensive analysis was repeated again on the mechanical stability of our coil against a large electromagnetic force to confirm the safety figure in our design.

Construction has also begun for the cryogenics and its automatic control system, and the return yokes have been machined on schedule.

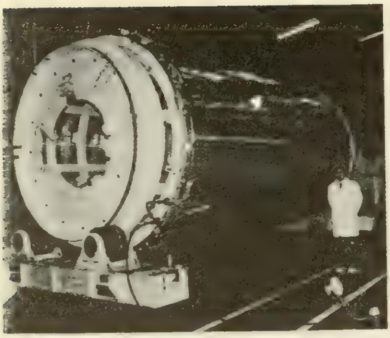


Fig. 35. TOPAZ superconducting thin solenoid. The coil is attached to the inner surface of this aluminum cylinder with liquid helium pipes seen outside.

Conclusion

Immediately after the completion of the experimental hall TSUKUBA in Oct. 1984, the cryogenic system for the magnet and the iron structure will be assembled. Installation of the solenoid and then its field measurement will follow. Major elements of the mechanical structure are under construction in accordance with this schedule. As an example, Fig. 36 shows octagonal end frames being fitted together.

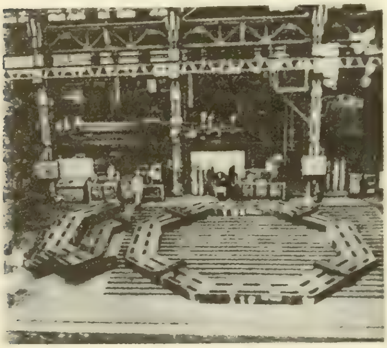


Fig. 36. TOPAZ octagonal end frames being fitted together. Muon detectors will be inserted into the spectrometer through the openings seen on the frames.

The detector construction should keep pace with this schedule. The progress made in 1983 has, in fact, ensured the successful start of mass production in the next year.

TRISTAN-EXP 003 / AMY Collaboration

University of Rochester, USA
Virginia Polytechnic Institute, USA
Ohio State University, USA
Korea University, Korea
Tokyo Institute of Technology, Japan
Saga University, Japan
University of Niigata, Japan
University of Saitama, Japan
KEK, National Laboratory for High Energy Physics, Japan

AMY, a high resolution lepton detector for TRISTAN, was approved in December 1983. This experiment is, unlike the other TRISTAN experiments, an international collaboration between US, Korean and Japanese universities and research institutes.

The detector is schematically shown in Fig. 37.

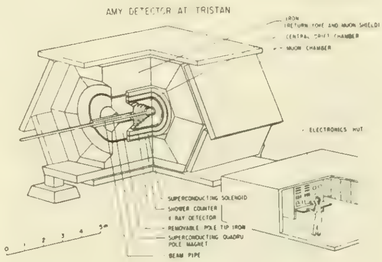
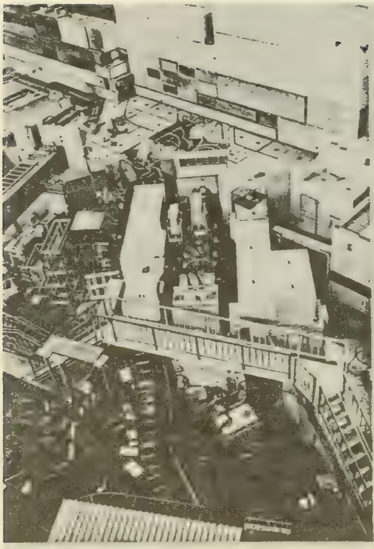


Fig. 37. A perspective view of the AMY detector.

With a 3 Tesla superconducting magnet 2.4 m in diameter and 1.5 m in length, the overall size of the detector is much smaller than that of the other two, while keeping characteristic high momentum resolution for charged track measurements. The central

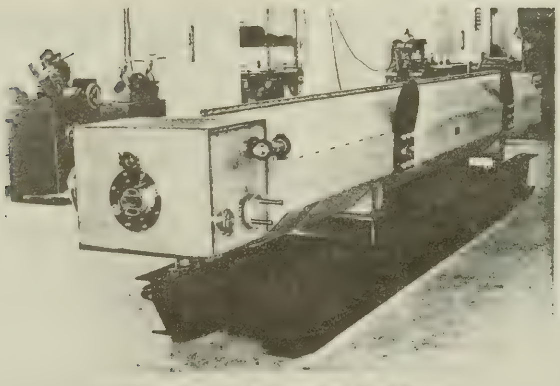
tracking chamber is a high resolution drift chamber 65 cm in diameter, and has about 8000 sense wires. The shower counter is a sandwich construction of lead sheet and wire chambers, and will be accommodated inside the solenoid magnet. This leaves only 75 cm for hadrons to travel before being absorbed in the shower counter and muon absorber. Due to this rather compact geometry, the decay probability of an emitted pion is only 0.5% at 5 GeV/c. Outside steel absorbers, 1.3 meter in thickness, there comes an x-y pair of muon chambers made of aluminum extrusion tubes. Each plane, x or y, consists of 2 identical planes of tubes staggered by a half cell. In order to improve the electron identification capability, an X-ray detector will be installed between the central drift chamber and the shower counter, and will detect synchrotron X-rays radiated by electrons in the strong magnetic field. The X-ray detector is a drift chamber of the Jet-Chamber type filled with Xenon gas. Another characteristic of the AMY detector is the possibility of a high luminosity configuration with micro-beta quadrupoles close to the interaction point. This configuration of quads is possible because of the absence of bulky detectors at the ends of the AMY detector.

Since the approval of the experiment in December 1983, the group has been involved in reviewing the construction work, designing the major components and strengthening the collaboration. Actual and extensitive construction will take place in FY 1984.



Overview of the K4 beam line

Physics Department



Assembled Hb Ti/Cu Superconducting Dipole Magnet

Major activity of physics department is related to TRISTAN project. But this will be covered independently in the section of TRISTAN project except for the activities of supporting groups, cryogenic group, electronics group and advanced technology group. Experimental researches using 12 GeV proton synchrotron remain active with almost a dozen themes explored. Non accelerator physics such as the measurement of neutrino mass using electron capture in ^{163}Ho or underground proton decay experiment has also been continued.

R and D activity includes that of BGO, BSO, Helicon, TRD, Lasertron etc. etc.

Theoretical studies cover broad area of physics; gravity, lattice gauge, nuclear physics etc.

Following pages will briefly summarize these activities.

EXPERIMENTS WITH 12 GEV PROTON SYNCHROTRON

During the FY 1983 (April 1982 ~ March 1983), the Proton Synchrotron was operated for 13 cycles and 311 shifts (about 2500 hours) were assigned to 9 physics experiments and 3 detector test experiments. All the experiments have completed the data-taking, including E113(ND) and E121(πI II) experiments, which were approved by the program advisory committee in the FY 1983.

The program advisory committee met three times (28th; Apr. 20, 29th; Oct. 31, 30th; Feb. 17 and 18) and examined 19 experimental proposals (E112 ~ E130). 5 proposals were approved and, E114(SKY), E117(Hy) and E125(dd) proposals are scheduled to be carried out after the PS operation shutdown of FY 1984. The approval of E119(pn), E126(πAX III) and E127(H) were deferred untill the next meeting. These proposals and the experiments running and analyzing in FY 1983 are listed in Table 1.

Experiment 49 (Λ)

Production of Polarized Λ Particles

The polarization of Λ's in the p + A → Λ + X reaction, in which A stands for Be, Cu and W, was measured by 12 GeV/c protons at production angles of 3.5°, 6.5° and 9.5°, and the results were already published (F. Abe et al., Phys. Rev. Lett. 50, 1102 (1983) and J. Phys. Soc. Jpn. 52, 4107 (1983)). Figure 1 shows an example of the results at the production angle of 6.5°. Cross sections for p + p → Λ + X are extracted from ones for CH_2 and C targets and the results are shown in Fig. 2, in comparison with previous data, which were measured with hydrogen bubble chambers.

Cross section analyses in terms of the A-dependence, the Feynman scaling, and triple-Regge have been completed for Λ's and the results are in preparation for publication.

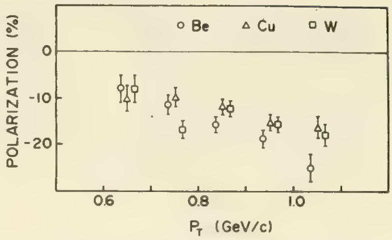


Fig. 1. The polarization of Λ° produced inclusively from Be, Cu and W as a function of the transeverse momentum p_T of Λ° at the production angle of 6.5°.

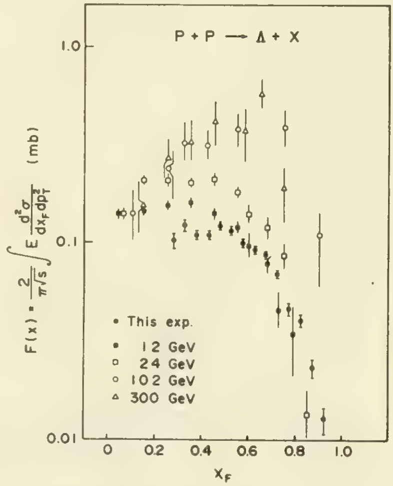


Fig. 2 The integrated invariant cross sections for p + p → Λ° + X as a function of the Feynman scaling variable X_F.

Table 1. List of experiment at the KEK 12 GeV PS

Exp. No. (Approved)	Spokesman (Group)	Title	Beam	Detectors	Amount of Run (at March 1984)	Status (at March 1984)
E49(Λ) (78/3/10)	K. Takikawa (Tsukuba)	Study of Asymmetry in $\Lambda \to pe\nu$, $p\mu\nu$ Decays by Hyperon Beam	Λ	Spectrometer Gas C	149.2	in Analysis
E62(pp) (79/3/22)	Y. Yoshimura (KEK)	Study of Exotic States in $\bar{p}p$ Reactions at 3 ~ 5 GeV/c	K1	HBC $\bar{p}$ Beam	1.5 M pic.	in Analysis
E64(π1) (79/6/1)	T. Tsuru (KEK)	Studies of 2π, 3π States in $\pi^- p$ Charge Exchange Reactions	π1	Spectrometer Lead Glass C	145.7	in Analysis
E68(ppc) (80/10/14)	M. Kobayashi (KEK)	Dectection of Discrete γ and π^0 from $\bar{p}p$ System	K4	Cylindrical MWPC, NaI, Glass Scinti	165.2	in Analysis
E74(ppR) (80/2/13)	K. Nakamura (Tokyo)	Baryonium in $\bar{p}p$ Reaction below 1 GeV/c	K3	Spectrometer NaI	149.1	in Analysis
E80(dpBC) (80/5/10)	F. Sai (Tokyo)	Measurements of dp Reactions in 2.0 ~ 4.0 GeV/c	K1	HBC d-Beam	200 K pic.	in Analysis
E81(KDEL) (80/5/10)	A. Masaike(KEK) G. Igo(UCLA)	Asymmetry in K^+d and π^+d Elastic Scattering around 1.5 GeV/c	K2	TELAS Spectrometer pd, d Target	180.3	in Analysis
E82(SPAL) (80/5/10)	S. Mori (Tsukuba)	Spallations of Nucleus by High Energy Particles	EP-2	SSD		in Analysis
E83(πD) (80/10/14)	Y. Sumi (Hiroshima)	Dibaryon Resonances in πd Scatterings	π2	Spectrometer	53	in Analysis
E90(πAC) (81/10/7)	K. Nakai (Tokyo)	High Energy Nuclear Interactions by using a Multiparticle Detector	π2	FANCY Spectrometer	154.5	in Analysis
E92(Σ) (31/10/7)	K. Miyake (Kyoto)	Measurements of Asymmetry in $\Sigma^+ \to p\gamma$ Decay	K2	TELAS Spectrometer	190.9	in Analysis
E94(πSTR) (81/6/15)	H. Itoh (Saga)	Reaction Mechanisms in πNucleus Interaction	π2	Streamer Chamber	37.4	in Analysis
T100(VENUS) (82/3/19)	Y. Fukushima (KEK)	Test for TRISTAN VENUS Detectors	T2			Running
T101(TOPAZ) (82/3/19)	T. Satoh (KEK)	Test for TRISTAN TOPAZ Detectors	T2			Running
T107(Liq. Ar)	T. Doke (Waseda)	Test for Liquid Argon Calorimeter	T1		11.5	in Analysis
E104(KuII)	T. Yamazaki (Tokyo)	Search for Heavy Neutrinos by $K\mu_2$ Decay	K4	Spectrometer NaI	149.0	in Analysis
E108(πAXII)	Iwata (Kyoto)	Measurement of Pionic X Rays	πμ	SSD	73.7	in Analysis
E110(πNucl II)	H. Yokota (Tokyo I. Tech.)	Particle Correlation by the π-Nucleus Interaction	πμ	Liq Scintillator	59.1 shifts	in Analysis
E111(Th)	R. Chiba (Tokyo I. Tech.)	Neutron Spectrum from p-Th Reaction	π2	Liq. Scintillator	20.3	in Analysis
E113(ND)	Y. Miake (Tokyo)	Deuteron from p-Nucleus Reaction	π2	Counter	34.7	in Analysis
E114(SKY)	B. Povh (Max-Planck)	Σ Hypernuclei by (K^-, π) Spectroscopy	K3	Spectrometer		in Preparation
E117(Hy)	T. Yamazaki (Tokyo)	Studies of Λ, Σ Hypernuclei by Stopped K^-	K3	Spectrometer		in Preparation
E119(pn)	K. Horikawa (Nagoya)	Spin Correlation Parameter Ann in pn Elastic Scattering	\	pol. p beam pol d target		in Preparation
E121(π1 II)	T. Inagaki (KEK)	Study of a few Pion States in π-p Charge Exchange Reaction	π1	Spectrometer Lead Glass C	62.4	in Analysis
E125(dd)	S. Yamamoto (Tokyo)	Studies of dd Interaction in the Range of 2 ~ 4 GeV/c	π2	MWPC		In Preparation
E127(H)	K. Miyake (Kyoto)	Search for a Stable Dihyperorn Resonance	K2	Spectrometer NaI		in Preparation

Experiment 62 ($\bar{p}$pBC)

Study of Exotic States in $\bar{p}p$ Reactions at 3-5 GeV/c

After the analysis for the inclusive production of K_s°, $K_s^\circ K_s^\circ$, $K^*(890)$ and Λ in $\bar{p}$ p interactions, the reaction $\bar{p}$ + Ta → V° + X (V°; K_s°, Λ,$\bar{\Lambda}$) at 4 GeV/c has been studied with pictures taken by the KEK 1 m Hydrogen Bubble Chamber in which two 4.4 mm thick Ta plates were installed. The production cross sections are summarized in Table 2, together with those in $\bar{p}$p at 4 GeV/c. If the strange particles are produced only at the primary interaction, the cross sections for $\bar{p}$-Ta should be 32.0 times larger than those for the $\bar{p}$p interactions due to A-dependence. The ratio for the inelastic cross section is nearly the value. But the measured ratios for Λ,$\bar{\Lambda}$and K_s° are 364 ±41, 8.9 ±4.2 and 43.2 ±3.5, respectively. It is not easy to explain only by K^- that the Λ production is surprisingly enhanced.

Table 2. Summary of the cross sections

Channel	Number of events	Cross section (mb)	Cross section in pp (mb)
Total		1628 ± 30	
K + X	445	82.0 ± 6.0	1.90 ± 0.07
Λ + X	929	193 ± 12	0.53 ± 0.05
$\bar{\Lambda}$ + X	21	3.8 ± 2.0	0.44 ± 0.05

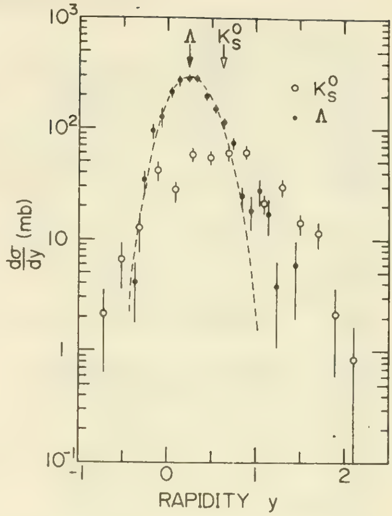


Fig. 3. Rapidity spectra of Λ and K_s°.

Figure 3 shows the rapidity distributions of K_s° and Λ from $\bar{p}$-Ta in the laboratory system. If one takes the $\bar{p}$ + 3N c.m. system for K_s° and the $\bar{p}$ + 13N c.m. for Λ, the peaks in the rapidity distributions go to 0, respectively. The rapidity distribution of Λ has an asymmetric tail on the higher side which lies just in the region of rapidity of Λ's from the $\bar{p}$p interaction. If one cut off Λ's with the momentum of higher than 0.6 GeV/c, we can obtain the symmetric rapidity distribution. Figures 4(a), (c) show the angular distributions for Λ and K_s° which are isotropic and indicate an evaporation process. The temperatures are calculated to be 97 MeV for Λ and 135 MeV for K_s°. In Fig. 4(b), the angular distribution of Λ with momentum above 0.6 GeV/c whose shape and magnitude are similar to those in the pp reaction.

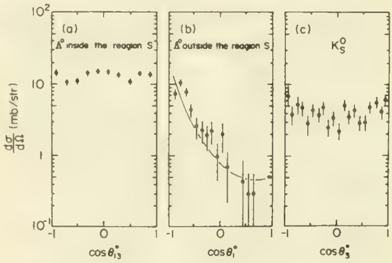


Fig. 4. Angular distributions of Λ and K_s°. (a) Λ with lower than 0.6 GeV/c in the $\bar{p}$-13N c.m. frame, (b) Λ with higher than 0.6 GeV/c in the $\bar{p}$p c.m. frame, but multiplied by 32.0, (c) K_s° in the $\bar{p}$-3N c.m. frame.

ready been completed, but analyses are still under way for the other reactions. Figure 10 shows the differential cross sections of the reaction $\bar{p}p \rightarrow \bar{n}n$. The results are compared with the predictions of some $\overline{N}N$ potential models. None of these models completely explains the behavior of the data. This indicates the necessity for fine-tuning of the parameters involved in the models.

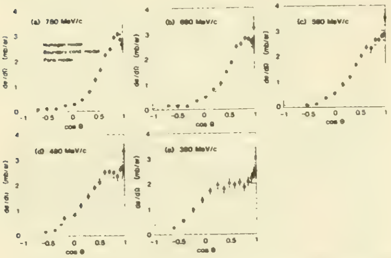


Fig. 10. The differential cross sections of the $\bar{p}p \rightarrow \bar{n}n$ reaction. The predictions of the Nijmegen model, boundary-condition model, Paris model are shown by the solid curves, dashed curves, and dotted curves, respectively.

Experiment 80 (dpBC)

Measurements of dp Reactions at 2.0 - 4.0 GeV/c

Approximately 5,000 frames per each incident momentum have been doubly scanned for all events. 55,000 scanned events were measured and spatially reconstructed in a standard way. Then these events were fitted to various kinematic hypotheses.

We have selected forward elastic scattering events whose chi-square of kinematical fit was less than 50 and $\cos\theta_{CM} > 0.0$. Using these elastic events, the angular distributions of forward elastic scattering and the slope parameters were obtained at 10 incident momenta. We then calculated the total elastic scattering cross sections using these slope parameters and the total cross sections.

We have investigated dp → ppn "non-spectator" breakup reaction. An event was accepted as belonging to the breakup hypothesis, if the chi-square probability of the fit was greater than 0.1%, and the missing mass was between 0.91 and 0.97 GeV. On the contrary to the results of Warsaw-Dubna collaboration, no enhancement is observed in the pn mass distributions from the charge retention breakup reaction, and in the pp mass distribution from the charge exchange breakup reaction. Here the charge exchange reaction is defined as a reaction in which the neutron momentum is the highest among the three nucleon momenta in the deuteron CM system, and the rest is defined as the charge retention reaction.

Experiment 81 (KDEL)

Asymmetry in the K^+d and π^+d Elastic Scattering by Polarized Deuterium near 1.5 GeV/c

Resonances like behaviors of P_{13}, P_{01} and D_{03} waves in the phase shift of K^+ N by the previous polarization data at KEK suggested the importance of the measurement of the K^+ d elastic vector polarization. Measurement of the vector polarization of the π^+ d elastic scattering by the polarized deuterium is useful to search for the effect of dibaryon resonances and that of the non-resonant amplitude from the Glauber approximation.

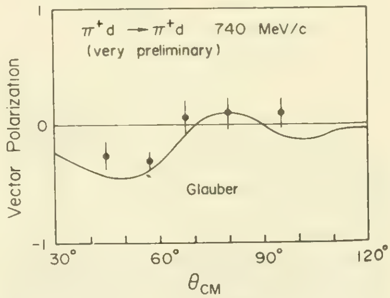


Fig. 11. Preliminary results of the vector polarization of πd elastic scattering at 0.75 Gev/c.

The vector polarization of the K^+ d elastic scattering was measured at 1.5 GeV/c and 1.7 GeV/c and that of the π^+ d elastic scattering at 0.74 and 1.5 GeV/c, using a large aperture spectrometer (TELAS) and a spin frozen deuteron target of deuterated pro-

panediol (D-8). Multi-wire proportional chambers and drift chambers were installed around the spectrometer magnet, in order to measure the momenta of the scattered and recoil particles.

Preliminary results of the π^+ d elastic scattering at 0.74 GeV/c are shown in Fig. 11. The solid line in the Figure is a prediction of the Glauber approximation without contribution from dibaryon resonances. The experimental results are consistent with the prediction of Glauber model, contrary to the differential cross section of πd elastic scattering which was measured by Hiroshima group (E-83).

Experiment 83 (πD)

Measurement of Differential Cross Sections for the Processes π^- d $\rightarrow$ π^- d and π^+ d $\rightarrow$ pp in Dibaryon Resonance Region

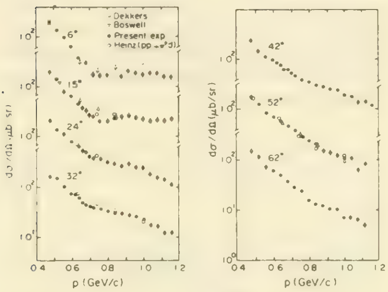


Fig. 12. The cross section of π^+ d $\rightarrow$ pp.

Measurement of the pion-deuteron elastic scattering have been completed and the results have already been published in refs. (M. Akemoto et al., Phys. Rev. Lett. 50 (1983) 400 and Phys. Rev. Lett. 51 (1983) 1838). A theoretical analysis of these data is now being in progress; Kanai et al. calculated the amplitudes using the Glauber model and a few dibaryon resonance. By using the majority of the existing data on the pion-deuteron elastic scattering the parameters of the model are determined. A tentative result is presented in a paper contributed to the 10-th PANIC to be held at Heidelberg.

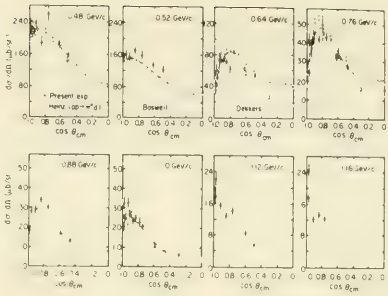


Fig. 13. Angular distributions of π^+ d $\rightarrow$ pp.

For the process π^+ d $\rightarrow$ pp, the analysis has been almost completed and the paper is now being in preparation. All the data for this process are shown in Fig. 12 in a form of the excitation function. Typical examples of the angular distributions are also shown in Fig. 13. The present data are in good agreement with other experiments. The most striking feature of the excitation functions is the existence of a break around 0.7 GeV/c at angles smaller than 32°. For larger angles, the excitation curves do not show any remarkable structure.

Experiment 90 (πAC)

Study of Space and Time Structure of High-Energy Nuclear Reactions

A spectrometer system "FANCY" has been successfully constructed and was used for experiments of high-energy hadron-nucleus reactions at the π2 beam line. Protons and pions are well identified at momenta up to 1 GeV/c by using dE/dx measurements in the chamber and time-of-flight measurements in the hodoscope. A typical event obtained by the "FANCY" is shown in Fig. 14.

Using the "FANCY" spectrometer, protons and pions emitted from reactions of 4 GeV/c protons on Al and Pb target nuclei were measured. Proton spectra in the target-fragmentation region were analyzed in a framework of a moving-source model in which we assumed that protons were emitted isotropically with a spectrum proportional to $\exp(-E/E_0)$ from a

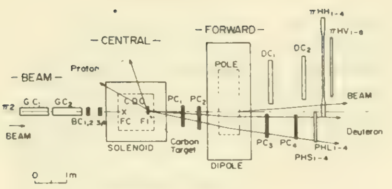


Fig. 14. Event observed by the FANCY spectrometer.

source moving with a velocity of β_0. The spectra showed an excess in a high energy region when fitted with single moving source. But they are fitted well with two moving sources as shown in Fig. 15. Parameters of a slowly moving source are consistent with our previous results dedued from low-energy spectra only (T.A. Shibata et al., Nucl. Phys. A408 (1983) 525). Moving-source parameters are shown in Fig. 16 as a function of charged-particle multiplicities in the target region. Parameters of slowly moving source are almost independent of the multiplicity, while those of fast moving source depend strongly on the multiplicity.

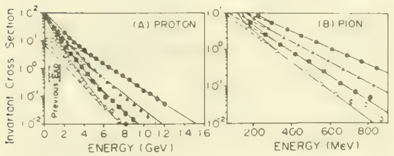


Fig. 15. Invariant cross sections for production of protons (A) and pions (B) at angles 45, 60, 75 and 85 degrees form 4 GeV/c protons on a Pb target.

From studies of correlation between particles in the backward and ones in forward directions, we have learned so far that (1) momentum distributions of forwarding protons shift toward lower side as a multiplicity in the backward increases, (2) the fast

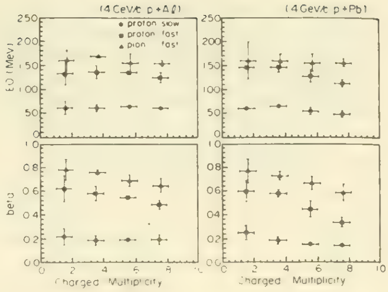


Fig. 16. The E_0 and β_0 parameters versus multiplicity of all charged particles.

component of proton spectra in the backward is significantly suppressed when tagged with high momentum leading protons, and (3) a clear signature from Δ particles could be seen in p-π invariant mass spectra.

Other subjects such as Δ^- and Λ-productions in projectile-fragmentation region (the HB-T effect) are also being analyzed to investigate general nature of high-energy hadron-nucleus reations.

Experiment 92 (Σ)

Measurement of the Asymmetry Parameter in the $\Sigma^+ \rightarrow p\gamma$ Decay

This experiment was performed to measure a parity violating amplitude for a $\Sigma^+ \rightarrow p\gamma$ decay. The asymmetry parameter α for the decay had been measured twice in the past both with bubble chamber experiments. The average value obtained was $\alpha = -0.70 \pm^{0.31}_{0.27}$. It has been shown theoretically that the asymmetry parameter α should be zero in the SU(3) limit with the certain fundamental assumptions such as the time reversal invariance for the interaction. The present experiment was planned to improve the statistical accuracy by factor ~ 2 using counter experiment techniques. The data taking was started from June 1983, and finished in February 1984. Off-line analysis is currently in progress.

In order to produce polarized Σ^+'s in this experiment, a reaction $\pi^+ p \rightarrow K^+ \Sigma^+$ was employed. A 1.7

GeV/c π^+ beam from K2 beam line at KEK was injected into a 30 cm long liquid hydrogen target, and scattered kaons and decayed protons were identified with aerogel Cerenkov counters (AC) and with a hodoscope of time-of-flight counters (TOF). There were two identical tracking arms, each of which consisted of 4 sets of multiwire proportional chambers (MWPC) and a set of drift chambers (DC).

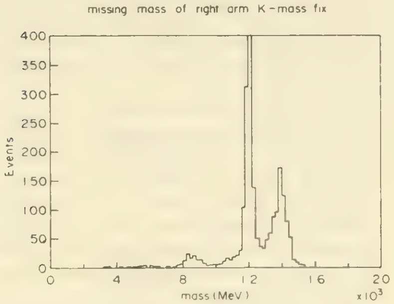


Fig. 17. Missing mass plot for K^+'s. Two peaks correspond to Σ^+ and Σ^+ (1385).

A C-type magnet (dubbed as TELAS), which provided a magnetic field of about 7 kG, was used to analyze momenta of charged particles in conjunction with these track chambers. It should be noted that the branching ratio of the $\Sigma^+ \to p\gamma$ mode is only 1/500 of the main mode $\Sigma \to p\pi^\circ$. Therefore, the most important point of the experiment was to distinguish these two modes effectively. To this end, two sets of gamma detectors were placed above and below the target to determine hit points of gamma rays. The gamma detectors were made of three identical layers, each being a sandwitch of a lead converter (one radiation length), a set of MWPC's and scintillation counters. The missing mass plot for kaons is shown in Fig. 17. A high peak in the middle corresponds to Σ^+ and a low peak on the right to Σ*(1385). The total number of Σ^+ samples is estimated to be more than one million events. The polarization of Σ^+ was also determined with the $\Sigma^+ \to p\pi^\circ$ decay mode, and was found to be about 0.7. This value well agrees with the data obtained at other experiment. Full analysis of the data will be completed within a year.

Experiment 104 (KμII)

Search for Heavy Neutrinos in the Decays $K^+ \to \mu^+ \nu_\mu$ and $e^+ \nu_e$

The data taking of the experiment 104 was completed in July 1983 and the data analysis is now on the way. The main purpose of the experiment 104 is to search for heavy neutrinos emitted in the two body decays $K^+ \to \mu^+ \nu_\mu$ and $K^+ \to e^+ \nu_e$. In 1980, we performed the first experiment (E89, Kμ) of the same purpose. From this experiment, the upper limit on $|U_{\mu_i}|$ was derived to be $10^{-4} - 10^{-8}$ in the neutrino mass range of 70-340 MeV/c^2, where $|U_{\mu_i}|$ is the mixing ratio between a heavy neutrino ν_i and the weak eigenstate ν_μ. In 1983, we performed the second experiment with better particle identification and higher sensitivity for smaller mixing ratio. A plan view of the experimental set up is shown in Fig. 18. The improvement of the apparatus is summarized as follows;

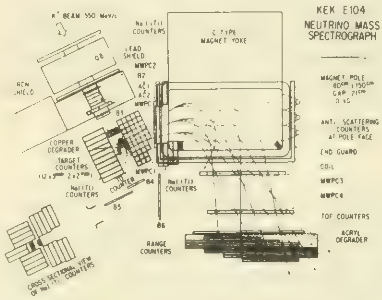


Fig. 18. A plan view of the experimental set up of E104 (KμII).

(1) In order to reject the most serious background events from $K^+ \to \mu^+ \nu_\mu \gamma$ decay mode. γ-rays were detected more efficiently by 206 pieces of NaI counters surrounding K^+ stopping region.

(2) To obtain higher momentum resolution, the track reconstruction and the energy loss correction were carried out more precisely by using the two-dimensional cathode-readout MWPC's and the

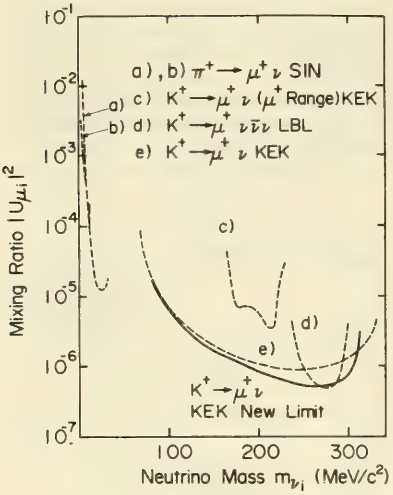


Fig. 19. Upper limit at 90% confidence level on $|U_{\mu i}|^2$ (the square of the coupling strength of mass eigenstate i to the muon-neutrino weak eigenstate) as a function of the neutrino mass.

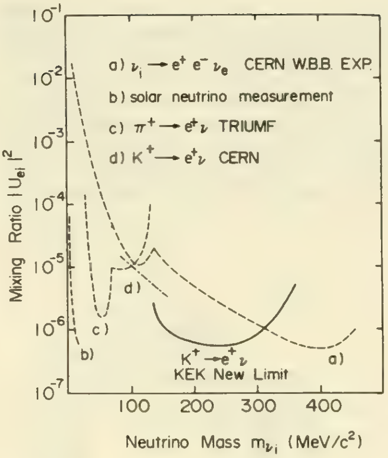


Fig. 20. Upper limit at 90% confidence level on $|U_{ei}|^2$ (the square of the coupling strength of mass eienstate i to the electron-neutrino weak eigenstate) as a function of the neutrino mass.

finely-segmented target counters. The momentum resolution of 1.8 MeV/c (FWHM) was achieved for 236 MeV/c μ^+ peak.

(3) The TOF counters were replaced by new larger ones with higher time resolutions. Thus the positrons were clearly separated from other particles.

The momentum spectra of muons and that of positrons were analyzed to search for anomalous peaks arising from the admixture of heavy neutrinos. In the present stage, the spectra have revealed no such peaks. Thus we obtain the upper limit of the mixing ratio $|U_{\mu_i}|^2$ to be 10^{-4} − 5 × 10^{-7} in the mass range of 70 − 300 MeV/c^2 and that of $|U_{e_i}|^2$ to be 4 × 10^{-6} − 6 × 10^{-7} in the mass range of 130 − 360 MeV/c^2. These new upper limits are displayed in Fig. 19 and Fig. 20 with the results from other experiments.

T107 (Liq. Ar)

A Pure Liquid Argon Calorimeter with High Energy Resolution for Electro-Magnetic Showers

In general, the energy resolution of fast (electron pulse) ionization chamber is limited by the sum of both contributions from electronic noise and ionization straggling, if the effect of residual ions, whose mobility is very low, is removed. If this principle is applied to liquid argon calorimeter, the energy resolution is mainly limited by electronic noise and is expected to be better than 1% (r.m.s.) for 1 GeV/c electrons. To study such a liquid argon calorimeter, called "pure" liquid argon calorimeter, we have constructed a new type liquid argon calorimeter with multi-parallel-plate type electrode system, which consists of 192 G-10 plates of 1.2 mm thick set with 9 mm spacing. This is a kind of "sampling" calorimeter but 80% of the absorbed energy in the calorimeter are deposited in liquid argon and its energy resolution can not be given by the formula usually used for sampling

calorimeters. In such a sense, we can also call this type of calorimeter "pure" liquid argon calorimeter. Figure 21 is a cross-sectional side view of the calorimeter consisting of an inner and outer stainless steel cylindrical vessels. The space between both vessels is evacuated during experiment for thermal insulation. The sensitive volume in the inner vessel is 2.0 m × 0.93 m^2. The inner vessel was filled with liquid argon directly supplied from a tank rully carrying liquid argon.

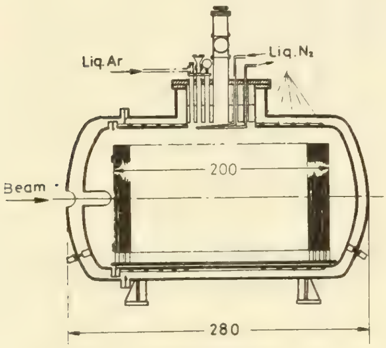


Fig. 21. A side view of the liquid argon calorimeter.

The experiments were done in the T-1 beam channel by using the electron beams from the internal target in the proton synchrotron in KEK. The saturation of ionization pulse height was considerably good. This shows that the purity of liquid argon used in the experiment is high. Figure 22 shows the variation of the energy resolution versus electron energy. The upper plots show the raw data and the lower plots are obtained by subtracting the electronic noise during experiment from the raw data. Thus obtained curve of resolution versus electron energy is not exactly proportional to $1/\sqrt{E}$, where E is the energy of incident electrons, but includes a constant term due to the momentum spread of electron beam (1.9 ± 0.2%). The intrinsic energy resolution obtained by subtracting the constant term can be expressed by the curve of $2.4/\sqrt{E}$ ± 0.2%, where E is expressed by GeV. This gives the best energy resolution for electrons around 1 GeV/c, except for that of NaI(Tl) crystal calorimeter, and is one expected from the formula for the energy resolution of the calorimeter previously derived by Hoshi, Masuda and Doke (Y. Hoshi, K. Masuda and T. Doke, Jpn. J. Appl. Phy. 21 (1982) 1086).

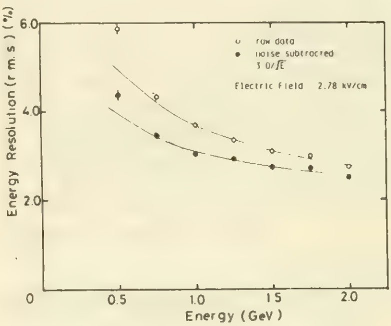


Fig. 22. The energy resolution versus electron energy.

Experiment 108 (ΠAXII)

Measurements of Pionic X Rays

The mesonic X rays (pionic-, muonic-, Kaonic X rays) are emitted from exotic atoms which capture negative mesons (π^-, μ^-, K^-) through the interaction between these mesons and orbital electrons of chemical substances.

The pionic X rays were measured with some compounds of multivalence atoms such as $Be_m B_n$, $As_m O_n$ and $Mn_m O_n$ and the intensity are compared with one of the X rays from the atoms in mixtures of the same components. Some experimental data are shown in Fig. 23. These results seems to support the assumption of molecular orbital interaction between electrons and pions in the first stage of pion capture in atoms.

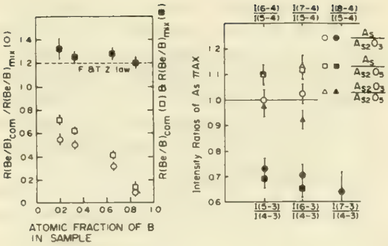


Fig. 23. (a) Intensity ratios of pionic X-rays vs. elemental abundance of B in Be-B. (b) Intensity ratios of As pionic X-rays for each transitions of As-O compounds.

Experiment 110 (ΠNUCL)

Study of Particle Correlation in Pion Absorption

In the previous experiment (E91), we measured the ratios (R) of pion absorption probability of a p-n nucleon pair to that of a p-p(n-n) nucleon pair in nuclei, and found that R was about 4.0 for light nuclei.

At the present experiment, we study in detail the process of absorption on P-wave nucleon pairs using ^{6}Li and ^{7}Li targets. Angular correlation of the ($\pi^\pm$, pp) and ($\pi^\pm$, pn) reactions were measured at the beam energy between 70 MeV and 160 MeV. Figure 24 shows the experimental arrangement. Neutron detectors are 6″ø × 6″ NE213 liquid scintillation counters and have thin (100μ SUS) front end. Proton detectors consist of two lines of plastic scintillators. A preliminary data analysis was performed for the incident energy of 70 MeV. Angular correlations of high energy (E_p , E_n < 30 MeV) nucleons show a peak at the angle corresponding to two-nucleon absorption. The angular distributions deduced for two-nucleon part of the (π, pn) reaction are shown in Fig. 25. these figures show clear asymmetry about 90°, and the shape of the angular distribution of (π^-, pn) reactions are very similar to that of the (π^+, pn) reaction.

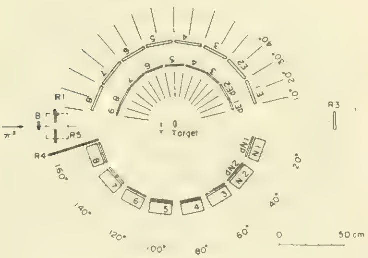


Fig. 24. Experimental arrangement of E110.

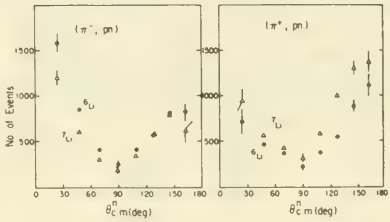


Fig. 25. Angular distributions of the (π, pn) reaction.

Experiment 111 (Th)

Measurement of neutron spectra from Th

In this experiment, we measured the inclusive neutron spectra from Th as a preliminary test. The purpose of the study is to obtain the basic data for the accelerator breeder and to understand the high energy nuclear reaction based on the moving source model. The accelerator breeder is very important since the shortage of ^{235}U resources is expected in future and the capacity of the fast breeder reactor is insufficient for the rapid production of nuclear fuel. The accurate values of the spallation cross-section is essential for the estimation of fissile production rate and for feasibility study of the accelerator breeder. The data are quite insufficient now, there is no reliable value of that for Th, which is a most important neutron source for the production of fissile through $^{232}Th + n \rightarrow {}^{233}Th \rightarrow {}^{233}Pa \rightarrow {}^{233}U$ reaction. On the other hand, we found from Experiment 90 that the neutron

the neutron spectra can be expressed in terms of formation of highly excited local moving spot and three stages of nuclear emission from the spots. In high energy nuclear reaction, it is interesting to know the neutron spectra of wide angular range and different incident energy with the heavy targets.

Neutrons were measured by 8 counter telescopes which consist of a liquid scintillator and a thin plastic scintillator are placed from 15° to 160° in plane for 4 GeV/c, 2.5 GeV/c and 1.5 GeV/c protons beam. Preliminary results shown in Fig. 26 indicate that the spectra seems to be expressed by intra nuclear cascade calculation except low energy part. (improved MECC7, evaporation is not included in the calculation)

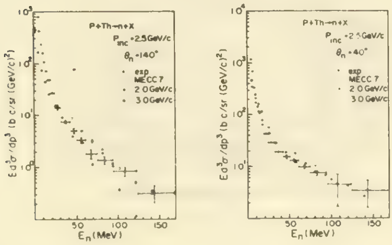


Fig. 26. Inclusive neutron spectra compared with intra nuclear cascade calculation of 2 and 3 GeV/c.

Experiment 113 (ND)

Production mechanism of Deuteron in pA collisions

Coincidence spectra of p and d in the quasi-elastic scattering have been measured at large momentum transfer in 3 GeV/c pA collisions. This reaction is considered to take place through a neutron exchange process between the incident proton and a quasi-deuteron in the nucleus. In our previous experiment at LBL, the following features are observed:

1. Quasi-deuteron is a proton-neutron pair, in which momenta of two nucleons are correlated anti-parallel.
2. Scattering from such momentum-correlated cluster seems to be an important source for emission of backward protons.
3. With a light target nucleus, the probability to observe pd in the quasi-elastic scattering is relatively high and kinematically clean. Therefore, this reaction can be used to study high momentum component of nucleon-nucleon correlation.

For the further study of the quasi-deuteron, it is necessary to determine the probability of quasi-deuteron in a nucleus and also the internal momentum distribution of nucleon inside the quasi-deuteron. Using the FANCY Spectrometer System, we have measured p and d over a wide kinematic region at p_{beam} = 3 GeV/c and 1.5 GeV/c. We have finished the data taking and are on the stage of analysis.

NON-ACCELERATOR PHYSICS

Measurement of the Mass of the Electron Neutrino using Electron Capture in ^{163}Ho

(KEK-Osaka-Tohoku-Tsukuba-Kyoto-TIT-INS-Tokyo Collaboration)

Our $m_{\nu e}$ -studies are now going on well, along the lines described in our talk at the Brighton Conference (S. Yasumi, Proc. of Int. Europhys. Conf. High Energy Physics, Brighton, 1983. 391). We have already obtained a relationship between $m_{\nu e}$ and the Q-value of ^{163}Ho using the value of $T^M{}_{1/2}$ and the nuclear matrix element relevant to the transition ^{163}Ho → ^{163}Dy. We are now trying to improve the precision of the $m_{\nu e}$ value, as determined from the Q-value, by reducing experimental uncertainties both in the total number measurement for ^{163}Ho atoms in the sources and in the M X-ray intensity measurement. For the former, we are measuring the total number of ^{163}Ho atoms in the sources using Isotope Dilution Mass Spectrometry as well as the PIXE method. Further, in order to remove the uncertainty in the thickness of the beryllium window in the Si(Li) detector used to measure M X-rays from ^{163}Ho, a windowless Si(Li) detector has been purchased from HORIBA Company Ltd. With this device, we have succeeded in obtaining a very beautiful M X-ray spectrum from a ^{163}Ho source.

If the Q-value of ^{163}Ho is determined independently, $m_{\nu e}$ can be obtained from the $m_{\nu e}$ -Q relationship mentioned above.

On the other hand, in order to determine both $m_{\nu e}$ and the Q-value simultaneously, we are doing studies of the M shell in dysprosium using monochromatic photons from the 2.5 GeV Electron Storage Ring in our Photon Factory.

The experimental setup is shown schematically in Fig. 27. Undulater radiations from the BL-2 line of the Light Source Ring are monochromated through a double-reflection monochromator made of beryl crystal and impinge upon a Dy target. Incident photon beams are monitored with a photon detector. We use beams with five different energies, E_a, E_b, E_c, E_d, and E_e where $E_a > E_{M1} > E_b > E_{M2} > E_c > E_{M3} > E_d > E_{M4} > E_e > E_{M5}$, and E_{Mi} ($i = 1 \sim 5$) stands for the binding energy of the Mi subshell as indicated in Fig. 28. The energy widths of these photon beams are a few eV and sharp enough to remain distinct from each subshell level. M X-rays emitted by dysprosium atoms excited by the incident photon beams, are measured with two Si(Li) detectors, one of which is set in the direction of the polarization of the photon beams (horizonal) and the other is set at an angle of 90° to the direction of the polarization of the photon beams (vertical), as shown in Fig. 27. If $S_{E\alpha}$ denotes the M X-ray fluorescence spectrum from Dy atoms excited by monochromatic photons having an energy E_α ($\alpha = a \sim e$), $S_{E\alpha}$ is represented by the following equation;

$$S_{E\alpha} = Nm \cdot \sum_i \sigma_i^{E\alpha} \cdot S_{Mi} \quad (i=1\sim5) \qquad (1)$$

where

S_{Mi} : M X-ray spectrum in the case where there is one vacancy in the M_i subshell only,

$\sigma_i{}^{E\alpha}$: photo electric cross section of the M_i subshell for a photon of an energy E_α,

N : total number of incident photons per second,

m : number of dysprosium atoms in a target per cm^2.

Rewriting equation (1) in detail, we have

$$\begin{aligned}
S_{Ea} &= Nm\left(\sigma_1^{Ea}\cdot S_{M1}+\sigma_2^{Ea}\cdot S_{M2}+\sigma_3^{Ea}\cdot S_{M3}+\sigma_4^{Ea}\cdot S_{M4}+\sigma_5^{Ea}\cdot S_{M5}\right)\\
S_{Eb} &= Nm\left(\sigma_2^{Eb}\cdot S_{M2}+\sigma_3^{Eb}\cdot S_{M3}+\sigma_4^{Eb}\cdot S_{M4}+\sigma_5^{Eb}\cdot S_{M5}\right)\\
S_{Ec} &= Nm\left(\sigma_3^{Ec}\cdot S_{M3}+\sigma_4^{Ec}\cdot S_{M4}+\sigma_5^{Ec}\cdot S_{M5}\right)\\
S_{Ed} &= Nm\left(\sigma_4^{Ed}\cdot S_{M4}+\sigma_5^{Ed}\cdot S_{M5}\right)\\
S_{Ee} &= Nm\left(\sigma_5^{Ee}\cdot S_{M5}\right)
\end{aligned}$$

If $\sigma_i{}^{E\alpha}$ is known, one can obtain S_{Mi} ($i = 5 \sim 1$) by turns using the above five equations. S_{M1} and S_{M2} in Fig. 28 are theoretical spectra which were calculated by T. Mukoyama.

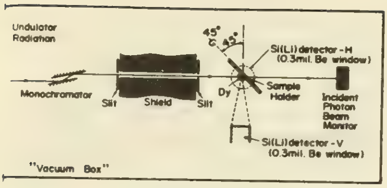


Fig. 27. Experimental setup for studies of the M shell in dysprosium using monochromatic photons from the 2.5 GeV Electron Storage Ring of the Photon Factory in KEK.

If $S_p^{^{163}Ho}$ stands for a photon spectrum from ^{163}Ho, where the number of photons per atom per second is plotted as a function of the energy of the photons, as shown in Fig. 28, we then have

$$S_p^{^{163}Ho} = \frac{1}{N_o}\frac{d}{dt}(S_{M1}\cdot N_{M1}+S_{M2}\cdot N_{M2})$$

$$= \frac{d}{dt}(S_{M1}\cdot n_{M1}+S_{M2}\cdot n_{M2})$$

$$= S_{M1}\cdot(dn_{M1}/dt)+S_{M2}\cdot(dn_{M2}/dt)$$

$$S_p^{^{163}Ho} = \lambda_{M1}\cdot S_{M1}+\lambda_{M2}\cdot S_{M2} \qquad (2)$$

where

N_{Mi} $(i=1,2)$: number of vacancies produced in the M_i subshell in the decay $^{163}Ho \xrightarrow{E.C.} {}^{163}Dy$,

n_{Mi} $(i=1,2)$: N_{Mi}/N_o ,

N_o : total number of ^{163}Ho atoms in the source,

λ_{Mi} $(i=1,2)$: partial Mi-capture decay constant.

Equation (2) tells us that when we reconstruct $S_p^{^{163}Ho}$ Ho using spectra S_{M1} and S_{M2}, these coefficients of S_{M1} and S_{M2} correspond λ_{M1} and λ_{M2} respectively.

An alternative way to get λ_{M1} and λ_{M2} is the following which is based on the fact that peak 1 in Fig. 2 comes from the M_1 subshell only and peak 2 in Fig. 28 comes from the M_1 and M_2 subshells:

If the intensities of peak 1 and peak 2 in $S_p^{^{163}Ho}$ are denoted by I_1 and I_2 respectively, we have

$$I_1/P_1^{M1} = dn_{M1}/dt = \lambda_{M1},$$

$$(I_2 - P_2^{M1}\times(dn_{M1}/dt))/P_2^{M2} = \lambda_{M2} \qquad (3)$$

where P_1^{M1} and P_2^{M1} stand for counterparts in S_{M1} for peaks 1 and 2 in $S_p^{^{163}Ho}$ respectively, and P_2^{M2} stands for a counterpart in S_{M2} for peak 2 in $S_p^{^{163}Ho}$ in Fig. 28.

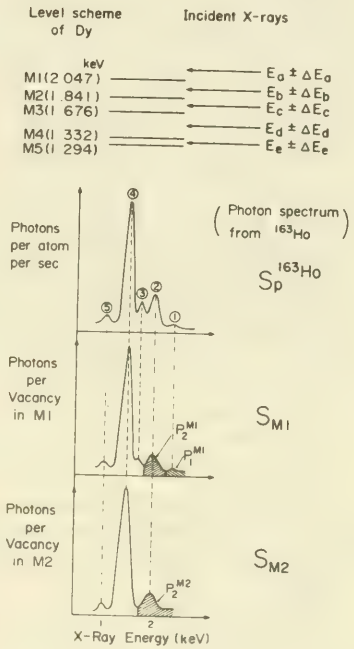


Fig. 28. Principle of the experiment. Spectra S_{M1} and S_{M2} are theoretical ones which were calculated by T. Mukoyama.

On the other hand λ_{M1} and λ_{M2} are expressed as

$$\lambda_{M1} = 2.799\times(Q-2.047)\cdot\sqrt{(Q-2.047)^2-m_{\nu e}{}^2}\times 10^{-12}$$

per sec.,

$$\lambda_{M2} = 0.1368\times(Q-1.841)\cdot\sqrt{(Q-1.841)^2-m_{\nu e}{}^2}\times 10^{-12}$$

per sec. - (4)

where $m_{\nu e}$ and Q are given in KeV.

Using λ_{M1} and λ_{M2} as determined experimentally (equations (2) and (3)), both $m_{\nu e}$ and the Q-value can be obtained from equations(4).

Some preliminary results has been recently obtained by us. As an example of S_{E_α} spectra experimentally measured, figure 29 shows a spectrum S_{E_a} together with the corresponding theoretical one where E_a =2.147 KeV. Spectrum S_{M5} is shown in Fig. 30, which was reduced from experimental spectrum S_{Ee} mentioned above. In the figure the corresponding theoretical spectrum is also shown.

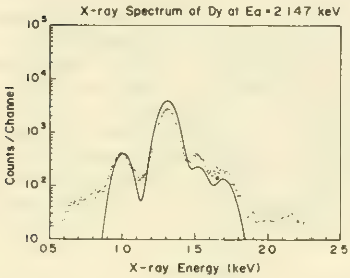


Fig. 29. Spectrum S_{E_a} where Ea = 2.147 KeV. A solid curve represents the corresponding theoretical spectrum which was calculated using theoretical spectra S_{Mi} slightly modified so as to fit both S_p^{163}Ho spectrum and S_{M5} spectrum in dysprosium.

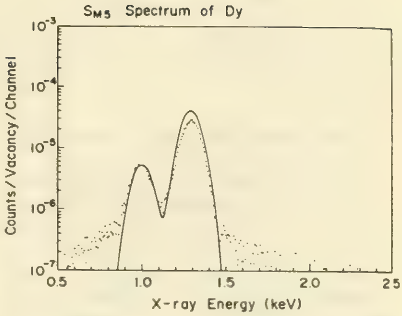


Fig. 30. Spectrum S_{M5}. A solid curve represents the corresponding theoretical spectrum slightly modified so as to fit both S_p^{163}Ho spectrum and S_{M5} spectrum in dysprosium.

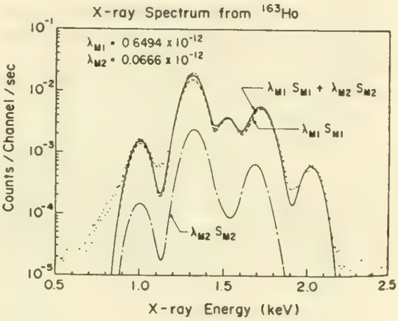


Fig. 31. Reconstruction of S_p^{163} Ho spectrum using S_{M1} and S_{M2}. A dashed curve and a dot-dashed curve correspond $\lambda_{M1}\cdot S_{M1}$ and $\lambda_{M2}\cdot S_{M2}$ respectively. A solid curve represents $\lambda_{M1}\cdot S_{M1}+\lambda_{M2}\cdot S_{M2}$.

Due to lack of the statistics, we tentatively analysed the data as follows: At first the theoretical spectra for S_{Mi} has been slightly modified so as to fit both S_p^{163}Ho spectrum and S_{M5} spectrum in dysprosium. Then, using the modified theoretical spectra for S_{M1} and S_{M2} thus obtained, S_p^{163}Ho spectrum was reconstructed (solid curve) as shown in Fig. 31.

The coefficients used in this reconstruction are:

$$\lambda_{M1} = (0.6494\pm0.1919)\times 10^{-12}\,\mathrm{sec}^{-1},$$

$$\lambda_{M2} = (0.0666\pm0.0197)\times 10^{-12}\,\mathrm{sec}^{-1}.$$

These two values give us the following tentative results for $m_{\nu e}$ and the Q-value:

$m_{\nu e}$ = 245±500 eV,

Q = 2.56±0.27 KeV.

Proton Decay Experiment at KAMIOKA

The detector construction of KAMIOKA Nucleon Decay Experiment (KAMIOKANDE) was completed by the end of May, 1983, after about two year's construction works on the cavity excavation for experimental site, the 3,000 m^3 steel tank, a water purification system, a preparation of more than, 1,000 large 20″ photomultiplier tubes and an associated electronic system. For final assembling the 1,000 phototubes in the tank, it took almost two months to install all of them, while filling the 3,000 m^3 water-tank with a pure water. Electronics and data acquisition system were also prepared and tested in parallel at the nearby electronics hut. After these preparatory works finished, the KAMIOKANDE detector finally became fully sensitive and started its operation at July, 6, 1983. The detector has been running very excellently since then, with a livetime efficiency of about 80%.

By the beginning of April, 1984, we have total 201 days of livetime, which means the sensitivity of 485 ton-years or 2.9 × 10^{32} nucleon years, with a normal fiducial volume of 880 tons for nominal nucleon decay events. The detector, thanks for its large photosensitive area of about 20% of its total area, has a very good energy resolution and an excellent pattern recognition capability. Thus, event scanning and analysis goes very smoothly with a week or so delay after taking data on the magnetic tapes.

So far we have obtained 80 events with event-vertices contained in the fiducial volume. Out of these 80 events, 59 events have a single Cerenkov ring and 21 events with two or more rings. Comparisons have been made with a detailed Monte Carlo program to simulate cosmic ray ν interactions, and it is seen that the most of events can be explained as ν-induced events. Two events still remain as a possible candidate for nucleon decay with a conceivable decay mode, the one with $p \to \mu^+ \eta^\circ (\to \gamma\gamma)$, $\to \mu^+ K^\circ (\pi^\circ \pi^\circ)$, or $n \to e^+ \rho^-$ and the other with $p \to e^+ \omega^\circ$ or $n \to e^+ \rho^-$ with ($\pi\gamma\gamma\gamma$)-four ring structure. The detector is continuing its steady non-stop operation with the present water transparency of more than 35 meter. For detailed information of the experiment and the performance, a reader is referred to the reports published elsewhere: (K. Takahashi; Proc. of the Third Workshop on Grand Unification, Univ. of North Carolina, N.C. U.S.A. in KEK Preprint 82-4, (1982), M. Koshiba; Proc. of 21 st. Int. Conf. on H.E. Physics, Paris 1982, Preprint UTLICEPP-82-04 (1982), M. Koshiba; Talk at the 1983 Int'l Symposium on Lepton and Photon Interactions at H.E. Cornell Univ. N.Y., August, 1983, and K. Takahashi, Proc. of the Mini-Conference on Low Energy Tests of Conservation Lows in Particle Physics, Virginia Polytech. Inst. and S.U., Virginia, September, 1983, Y. Totsuka; A talk given at the XIX th Rencontre de Morionde, La Plagne, Feb 26 - March 4, 1984.)

BEAM CHANNELS AND INSTRUMENTAL FACILITIES

BEAM CHANNELS

Operation and Maintenance of Beam Lines

In FY 1983 the beam lines around the 12 GeV Proton Synchrotron were operated for nearly three thousand hours to perform the physics experiments and various tests. The beam line parameters are listed in Table 3.

As described in the previous reports, we have the slow extracted proton beam, EP2, which is split into three ways as shown in Fig. 32. The first split beam, EP2-A, is hitting the production targets of the K2 beam line and the πμ beam channel. The second split

Table 3. Summary of KEK beam lines in FY 1983

Beam	Momemtum Range (GeV/c)	Momemtum Bite ($\pm \Delta p/p$%)	Production Angle (°)	Solid Angle (msr)	Particles	Typical Flux per Pulse
EP1	4-13	Fast Extracted Beam			p	5×10^{10}
-A						
EP2-B	4-13	Slow Extracted Beam			p	3×10^{12}
-C						
$\pi 1$	4-8	2	1.5	0.33	π^+ π^-	$2 \times 10^6/6 \times 10^5$ at 8 GeV/c
$\pi 2$ [i]	1-1.3	1	10	0.59	π^+/π^-	$2 \times 10^5/1 \times 10^5$ at 3 GeV/c
T1 [i]	0.5-2.3	2	23	0.16	π^+/π	$5 \times 10^4/4 \times 10^4$ at 1 GeV/c
					K^+/K	$5 \times 10^3/1 \times 10^5$
K2	1-2	3	0	1.0	$p/\bar{p}$	$1.7 \times 10^7/1.5 \times 10^4$ at 2 GeV/c
					π^+/π^-	$2.2 \times 10^7/1.5 \times 10^7$
					K^+/K^-	$4.2 \times 10^4/1.0 \times 10_4$
K3	0.5-1.0	2.5	0	7.3	$p/\bar{p}$	$7 \times 10^7/3.5 \times 10^2$ at 0.55 GeV/c
					π^+/π^-	$5 \times 10^7/5 \times 10^7$
$\pi\mu$	0.1-1.0	6	87	20	π	1.2×10^5 at 0.25 GeV/c
T2	1.0-6.0	3	15	0.38	$\pi^{\pm}$	10^4 at 4 GeV/c
K4	0.4-0.8	3	0	7.0	$\bar{p}$	700 at 600 MeV/c

i. Internal Target Beam Line

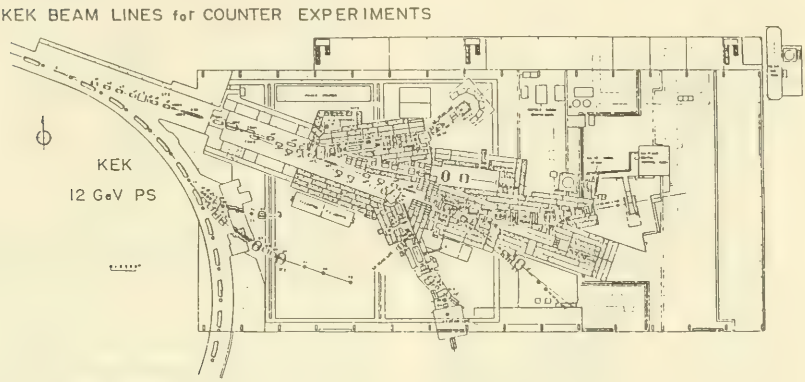


Fig. 32. KEK Beam Lines for Counter Experiments in 1983.

beam, EP2-B, is irradiating the production target of the π1 and T2 beam lines. The third one, EP2-C, is hitting the production target of K3 and K4 beam lines. K4 beam line construction is completed in the fall of FY 1983.

The internal target beam lines, π2 and T1, are still operating for the experiments and the detector testings. The typical proton intensities of the EP2-A, EP2-B, EP2-C and the internal target were 1.0×10^{12}, 0.8×10^{12}, 1.5×10^{12} and 1.5×10^{11} ppp, respectively. These intensities were strongly dependent on the accelerated proton beam intensity and the phase space emittance of the extracted proton beam.

The major experiments performed in FY 1983 with the K2, π1, K3 and π2 beam lines were E92 (Σ), E64, E121 (π1), E99 (Kμ), E68 ($\bar{p}$pc) and E90 (πAC), respectively. The status and results of these experiments are given in the previous chapter.

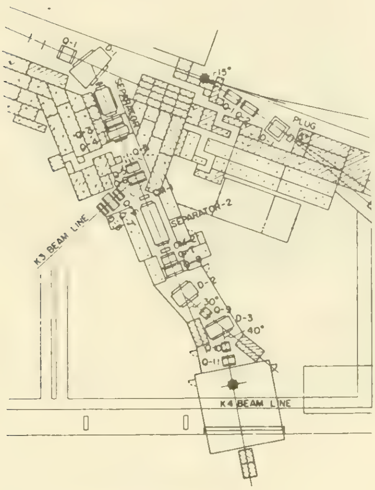


Fig. 33. Layout of the K4 beam line.

A special radiation shielding concrete blocks, containing high percentage of limestone ($CaCO_3$), were tested in FY 1982. Although the special shielding blocks had the same neutron attenuation length as normal concrete blocks, we found that the special blocks had very small residual activities after the irradiation with high energy protons and neutrons. Some amounts of this new material were installed on the ceiling of the EP2-C beam line to reduce the radiation level of the site boundary.

Three emergency exits from the slow extracted proton beam line tunnel (EP2) are furnished at the splitter magnet area, the K2 beam separator area and the π1 beam line downstream end. In the case of emergency such as a fire, one could quickly get out

Table 4. Characteristics for K4 beam

Momentum range	0.4 – 0.8 GeV/c
Target	5 × 10 × 60 mm³ platinum target
Central production angle	0 deg
Beam length	28.51 m
Solid-angle acceptance	7 msr
Horizontal acceptance	± 200 mr
Vertical acceptance	± 11 mr
Momentum bite	± 3.0% P/P
Solid-angle momentum acceptance	34.1 msr% P/P
Electrostatic separators	
First one	length 1.88 m gap 15 cm field 40 kV/cm with a crossed magnetic field
Second one	length 3.0 m gap 12 cm field 50 kV/cm no crossed magnetic field
At the first mass slit	
Horizontal magnification	−8.69
Dispersion	3.98 cm/% P/P
Vertical magnification	−0.421
Separation between p and π	1.41 cm at 800 MeV/c
Angle between the mass slit and the central trajectory	30 deg
At the second mass slit	
Horizontal magnification	−3.51
Dispersion	1.08 cm/% P/P
Vertical magnification	0.989
Separation between p and π	4.0 cm at 800 MeV/c
At the beam end	
Horizontal magnification	4.00
Dispersion	−0.45 cm/% P/P
Vertical magnification	−0.935
Horizontal image size	5 cm
Vertical image size	4 cm
Horizontal divergence	± 70 mr
Vertical divergence	± 30 mr
Yield expected for 10^{12} protons	
700 $\bar{p}$ is expected at 600 MeV/c with π μ e⁻/$\bar{p}$ ratio of less than 10	

from the primary proton shielding tunnel through these exits.

The superconducting 8 GeV/c unseparated beam line, $\pi 1$, was operated through the year for the experiments E64 (πI) and E121 (πI-II). In this beam line we have five conventional magnets and three superconducting magnets: a 2 Tesla septum bending magnet, two large aperture 4 Tesla bending magnets. A large aperture superconducting spectrometer magnet (BENKEI) was also operated together with the $\pi 1$ beam line. We have operated the $\pi 1$ beam line and the BENKEI spectrometer magnet for more than ten thousand hours in the superconducting state so far. The purposes of introducing superconducting magnets in the beam line and the spectrometer system is to grade up the performances with high magnetic fields, and to save energy consumption. The experience of the construction and the operation of this system will very helpful for the construction of more sophisticated superconducting magnet systems in the future.

A high momentum test beam line, T2, constructed in FY 1982. This beam line was very useful for various testing of TRISTAN detector elements, such as lead glasses, scintilators or various chambers.

A low momentum antiproton beam line, K4, was designed and constructed for the experiment E68 (ppc). This beam line is a branch of the K3 beam line. Double stage mass separation system was adopted to get a antiproton beam with less contaminating particles. The design parameters of the K4 beam line are given in Table 4. The layout of the beam line is shown in Fig. 33 and the overview of the downstream part of K4 beam line is shown in the front page of the physics department. The beam line construction is completed in the summer of FY 1983, after replacing K3-D2 by K4-Q5 and Q6. The experiment E68($\bar{p}$pc) started this fall with this new beam line.

In the EP2 tunnel, many ITV cameras are installed to watch primary beam, target area or some beam line elements. These cameras used to be damaged very often by a strong radioactivity in the tunnel. Semiconductors in the cameras were mainly responsible for these damages. A camera in which some semiconductors were replaced by electronic tubes was developed. This type of cameras will be made in FY 1984 and will be tested in the EP2-tunnel after the long shutdown.

In FY 1984, we have a long scheduled shutdown of the 12 GeV Proton Synchrotron for the TRISTAN tunnel excavating under the proton synchrotron accelerator facilities. During this shutdown period, beam lines have been planned for the next generation of physics experiments with the 12 GeV protons. Since the beam line elements have been operated for nearly ten years, some of them have serious damages. A part of targets, slits, magnets and shieldings will be replaced by new ones.

Cryogenic Facility

The helium refrigeration system of 8 GeV/c pion beam line was operated for the experiment of E-121. This helium refrigeration system has started test operation in FY 1981. The total operation is approximate 11000 hours in Feb. 1984. The operation statistics from FY 1981 to FY 1983 is showed in Table 5.

Hydrogen Targets have been used for the experiments E-121, E-92 and E-68 in this year. The appendix for E-68 had a large capacity that was about 3 ℓ and made a thin-stainless steel. So that Target was used refrigerator of large refrigeration power.

The design of cryogenic systems for VENUS and TOPAZ superconducting solenoid magnet began in this year. In FY 1983, it constructed cold box and screw compressor of VENUS cryogenic system, and then it constructed cold box and control dewar with liquid He pump of TOPAZ cryogenic system. The control systems have been designing on the computer control, and it ordered distributed control systems and mini-computers. Figure 34, 35 show a cryogenic system flow diagram of VENUS and TOPAZ.

Table 5. Operation hours of $\pi 1$-helium refrigeration system

Fiscal Year	1981	1982	1983
Operation hours of Compressor	2739h	4772h	3878h
Integral Operation hours of Compressor	2739h	7511h	11389h
Operation hours of Turbine	1664h	4089h	3197h
Integral Operation hours of Turbine	1664h	5753h	8950h

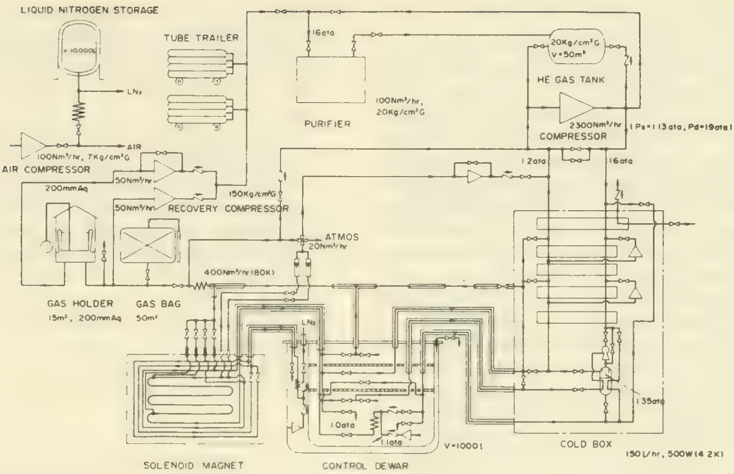


Fig. 34. Cryogenic System of the VENUS solenoid magnet.

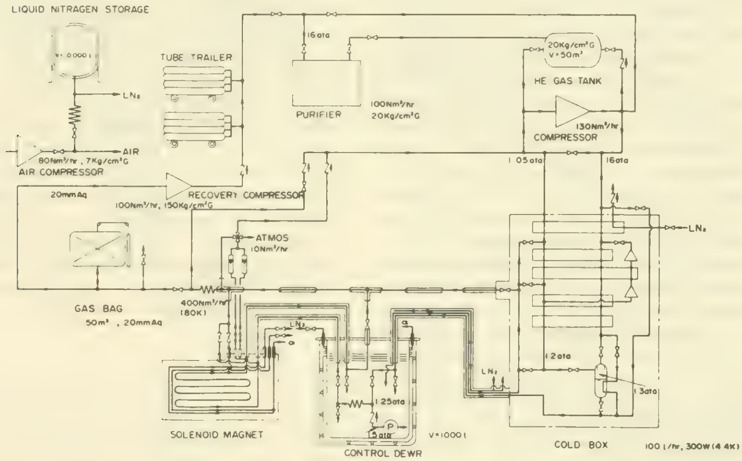


Fig. 35. Cryogenic System of the TOPAZ solenoid magnet.

Electronics and On-line computer facilities for High Energy Experiments

Electronics group supported standard electronics for high energy experiments at 12 GeV proton synchrotron. Recent experiments use a number of channels of calorimeter counters and cathode readout of wire chambers. Such experiments require many channels of ADC with 12 bit resolution. For supplying ADC's for these applications, home-made ADC was developed as a CAMAC module with 16 channels per card.

The other main activity of this group is contributions to the development of electronics system for TRISTAN experiments. Large TDC system for VENUS drift chamber was designed in the framework of FASTBUS and prototyped in cooperation with VENUS experimental group. The system consists of 23 TAC modules (32 channels per module) and 1 ADC module in a FASTBUS crate. The digitized data are corrected for linearity and pedestal subtraction, and stored in a buffer memory which are readout through Segment Interconnect.

The readout electronics of time of flight counters for both VENUS and TOPAZ detector was studied for high accuracy in the time measurement. The prototype module implemented in CAMAC in being built for evaluation of the circuit which included two pairs of ADC and TDC channels for a counter unit.

The linear summing amplifier was designed last year for energy sum trigger by barrel calorimeter and built the production version in this year. The prototype of pre-amplifier for drift chamber was designed and hybridized for systematic test of signal transmission from the chamber to the TDC system.

FASTBUS is new international standard for data acquisition system for high energy experiments. In the TRISTAN experiments the FASTBUS has been adopted as the standard for data gathering system to on-line host computer VAX(DEC). In this year, the modules of key element for the data aquisition system have been built. These are VAX-FASTBUS Processor Interface, Motrola 68000-FASTBUS Processor Interface, FASTBUS Cable Segment, Simplex Segment Interconnect, FASTBUS-personal computer interface, and ancillary logic units of Crate Segment. Individual elements have been tested successfully. For the overall test under the realistic condition, we have to wait the completion of the analog readout modules untill next year.

In this year, micro computer system is standardized by On-Line group for TRISTAN experiment with MICRO/PDP(DEC) which are distributed for each detector element. The main usages are monitoring and tuning up of each detector, independently. These are used separately in the phase of detector construction and connected to the host computer VAX through Ethernet local area network after the installation of all detector elements. The basic software tools for programming of the data taking through CAMAC system were prepared by On-Line group.

The networking of various computers and terminals is very important facility not only for efficient usage of computer resources, but also for communication and information exchange between users and between machines. On-Line group supports more than 30 low cost ASCII terminals as a full screen terminal of VAX and M-200H through the portselector and 9415/E emulator in cooperation with the Data Handling division. The present status of the interconnection of computers and terminals is shown in the figure below. The access from outside of the laboratory is available through so called TRISTAN-NET which links computers of member universities via the packet exchange network of NTT (DDX) as shown in the figure. The network was implemented at five universities in this year. The other universities will be linked in the coming years.

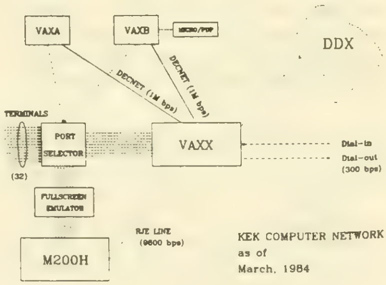


Fig. 36. KEK Computer Network as of March, 1984.

RESEARCH AND DEVELOPMENT OF MAGNETS AND DETECTORS

Development of Superconducting Accelerator Magnet

Although the construction of a superconducting proton ring in the TRISTAN tunnel is deferred, we have continued the basic study on engineering problems of the superconducting magnets. Based on the successful experience in several short length dipole magnets, we have constructed a five meter long prototype NbTi/Cu dipole magnet in FY 1982 ~ 1983. This magnet is a 5 T NbTi/Cu accelerator dipole of warm bore and warm iron. The coil inner diameter is so large as 140 mm and the coil length is 5.1 m. The other main design parameters are given in Table 6. The coils were wound in double shell with a Keystoned Rutherford cable of 27 NbTi/Cu strands. The cable is mainly insulated with Kapton tapes and small amount of epoxy resin. These coils were cured in a set of strong jigs and then tightly clamped with 316L stainless steel collars by welding in a hydraulic press. The cross-sectional structure of this dipole is similar to that of the Fermilab Tevatron dipole except for the size.

The trainings could be reduced by application of higher prestress at the clamping of coils. These coils were assembled in the warm iron laminated yoke together with the horizontal cryostat. The overview of the magnet is shown in the figure on the front page of the physics Department. The design parameters of this prototype dipole magnet are given in Table 6.

Table 6. Main design parameters of the Prototype NbTi/Cu dipole

Coil inner diameter	140 mm
Warm bore diameter	90 mm
Coil length	5.10 m
Magnetic length	4.82 m
Collared coil weight	2 t
Total magnet weight	9.5 t
Central field	5 T
Current at 5 T	4,870 A
Stored energy	1.6 MJ
Inductance	135 mH
Bursting force	2×10^9 N/m

Transition Radiation Detector

The transition radiation detector (TRD) is a promissing detector for particle identification at extremely relativistic region. In the VENUS detector of TRISTAN, there reserved a room for particle identification detector within the superconductive solenoid. The function of the TRD in the VENUS detector is a positive identification of electrons from large pion background in a multi-particle jet event. The TRD provided independent and additional pion rejection power to the lead glass calorimeter.

As the first step of the development, several radiator materials were tested on the emission efficiency of transition radiation photon. The radiators are carbon fiber, polypropylene fiber, polypropylene sheet, Mylar sheet, and plastic foam in the realistic size within the detector. The parent electrons are swept out of the chamber by a magnet after passing through the radiator. The emitted photons were guided through He-bag and detected with a Xe-filled wire chamber. The photon spectra and emission efficiency were measured with charge-integration ADC and compared to the theoretical calculation. As the best material among the radiators tested, we chose polypropylene fiber which showed high emission efficiency and is convenient for installation to a large cylindrical detector.

Further test with the polypropylene fiber were carried out for finding the optimum density and length of the radiator and chamber within the allowed space. In this experiment, single layer of radiator and chamber was used as shown in the Figure 37. The real detector has multi-layer of the radiator and chamber. In order to simulate in the data analysis. Following this way, electron-pion separation was examined at 2 GeV/c by comparing the truncated mean distributions of the pulse height for pion and electron beam. The signals of electrons include the transition radiation photons in addition to the ionization loss in Xe gas. A typical data is shown in the Figure 37. The resultant pion contamination (%) is plotted as a function of the electron detection efficiency. In the analysis, 4 and 6 layers configuration were simulated. For comparison, the data of Buengener et al. (Nucl. Instr. and Methods, 214 (1983) 261) is shown in the &Fi.gure. The expected performance of the TRD in the VENUS detector is the pion rejection factor of 1/20 - 1/50. Extensive test for radiator and chamber structure has to be fol-

lowed for the construction of the large cylindrical TRD.

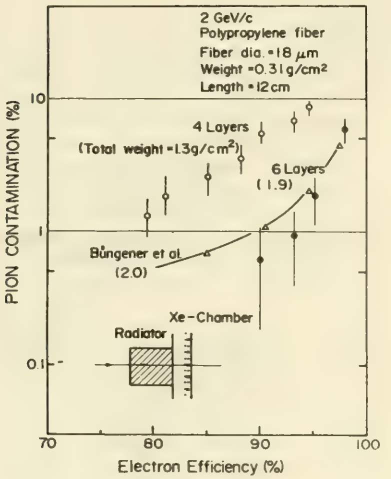


Fig. 37. Pion contamination (%) as a function of electron detection efficiency with the simulated 4- and 6-layers transition radiation detector. The radiator is a stack (0.31 g/cm**2) of polypropylene fiber of 18 micons diameter.

Heavy liquid counter (HELICON)

It was mentioned in the original mineralogical paper written by Clerici (E. Clerici: Atti Acad. Naz. Lincei (R-5) 16I (1907) 187) that a water solution of glycolic thallium has a density d = 3.95 g/cc and that of lactic thallium d = 3.40 g/cc. However, he stated that the viscosities of those liquids were so high and that it was inadequate to use them for mineral separation; therefore, no mention was given of transparencies or colours for these liquids.

We have processed glycolic thallium and lactic thallium and dissolved in water. The resultant heavy liquids were opaque immediately after the dissolution in water. After heating the liquids to about 80°C and extracting the water, these liquids became colourless solutions of high viscosities and kept the transparent colourless states while these were cooled down to the room temperature around 20°C. If the liquids were cooled further down to 0°C, these tended to crystalize and this tendency strongly depended upon the amount of water left in the solution for both cases. It is likely that the liquids are in metastable states around this temperature region.

These properties are extremely analogous to that of the mixture of lead acetate and lead propionate dissolved in water (T. F. Bolles and P. B. Fleming: U. S. Patent No. 3,937,970 (1976), A. Kusumegi and Y. Yoshimura: Nucl. Instr. and Method, in press) but with the viscosity less than that of lead acetate-propionate mixture. The measured transmission of glycolic thallium solution is shown in Fig. 38 and that of lactic thallium in Fig. 39 (A. Kusumegi and Y. Yoshimura: to be reported). For both cases, the transmissions did not reach to 100% as slight opacities already appeared in our samples at the time of spectroscopic measurement. These opacities could be removed by careful control of processing of those liquids, particularly, of extracting the water from these solutions.

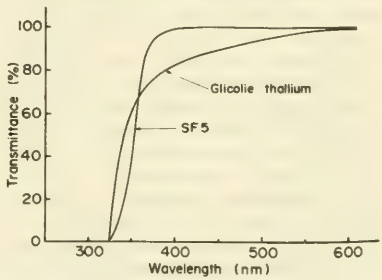


Fig. 38. The transmittance of glycol thallium solution as a function of wavelength in comparison with an SF 5 lead glass.

The inclusion of an organic liquid scintillator, xylen with PPO, was tried. It was much easier to do for these liquids than for thallium formate or for thallium formate-malonate mixture as no surfactant was required for mixing the liquid scintillator with these liquids to an amount of 10-20% in volume. However, the scintillation signals were strongly quenched for

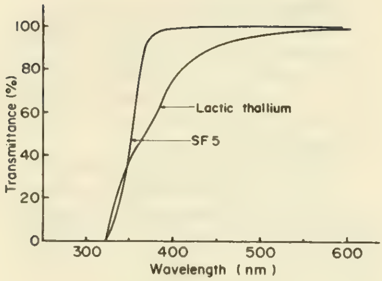


Fig. 39. The transmittance of lactic thallium solution as a function of wavelength in comparison with an SF 5 lead glass.

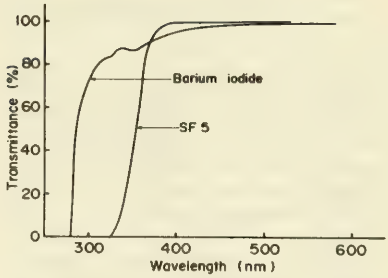


Fig. 40. The transmittance of barium iodide solution as a function of wavelength in comparison with an SF 5 lead glass.

these liquids in the same way as that for the lead acetate-propionate mixture (A. Kusumegi and Y. Yoshimura: Nucl. Instr. and Method, in press).

From the practical point of views of economy Development of Superconducting Accelerator Magnet of this solution was satisfactorily good as a and toxity, barium iodide (BaI_2) is one attractive material for transparent heavy liquid. The solubility of BaI_2 against water is 185 g per 100 cc at 10°C and it forms a heavy liquid of the density d = 2.14 g/cc. The calculated radiation length for this solution is X_0 = 5.4 cm. The measured transmission of this solution was satisfactorily good as a Cherenkov radiator as shown in Fig. 40 (A. Kusumegi and Y. Yoshimura: to be reported). We plan to test it with the beam as soon as PS restarted the operation in 1985.

So far no systematic investigation was made on the structure of heavy liquid of thallium formate or thallium malonate. The group of H. Ohtaki first investigated the structure and some physicochemical properties of thallium(I) formate solutions (H. Ohtaki et al.: to be reported to Int. Conf. of Complex Salts, Colorado, July 1984). The structure of aqueous solution of thallium(I) formate of 10.77 mol/dm^3 (d = 3.189 g/cc) was determined by X-ray diffraction method by using a θ-θ type diffractometer at 25°C. From the analysis of the raidal distribution curve and the structure factors of solution, it was found that thallium(I) ions combined with formate ions to form the tetramer, $T\ell_4(HCOO)_4$, in the solution as shown in Fig. 41 and the interatomic distances with the complex were determined. The details will be published in near future (K. Ozutsumi: Ph. D. Thesis, Tokyo Inst. Technology (1984)).

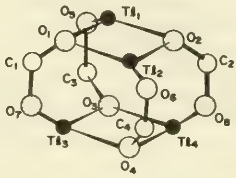


Fig. 41. The structure of $T\ell_4$ (HCOO)$_4$ complex in solution.

THEORY GROUP

People in our theory group have been engaged in a wide variety of research activities, ranging from a numerical computation of low energy hadron spectrum to application of unified theories to cosmology. Only a brief summary of activities is attempted here.

Quantum chromodynamics, believed by many to be the ultimate field theory of strong interactions, is producing interesting numerical data that can be compared with experiments. The basic method is Monte Carlo simulation on a discrete spacetime lattice (lattice gauge theory). In collaboration with outside people (Fukugita, Ukawa, Iwasaki, etc.), our group has performed extensive calculations, using computer facilities of our laboratory. Although results are in general encouraging, statistics of data is not enough and a larger capability of computers is clearly called for. Kaneko et al., for the first time, studied violation of the OZI rule and mixing of glueballs with flavor singlet mesons in the SU(2) lattice gauge theory. A behavior of OZI violating amplitudes is obtained for light and charm quarks.

The SU(2) × U(1) electroweak theory is in better shape in view of experimental confirmation of W and Z bosons at CERN. Yet much remains to be unexplained in this standard theory: masses and mixing parameters of quarks and leptons, origin of the Higgs mechanism, etc. Sugawara, in collaboration with Brown, Deshpande, Pakvasa and Yamanaka, studied CP violation, K-M matrix etc. within the framework of a discrete symmetry (S_3) of Higgs model.

Grand unified theories gave rise to an interesting possibility of monopole-catalyzed proton decay (Rubakov effect). Kazama continued to investigate various aspects of this problem. Mechanism of the conservation of the electric and the color charges, despite the lack of it in the boundary condition, was clarified by extensive calculation. Kazama further examined some effects which tend to suppress the catalysis process: (1) Unbalance of the weak charge in the process was pointed out and (2) the radiative decay rate of the fermionic state with vanishing angular momentum was calculated. Kobayashi, together with Sakamoto, investigated radiative corrections in the strong magnetic field of monopole.

Kaluza-Klein (KK) theories are an interesting attempt to unify gauge interactions with gravity. Kobayashi and Sugamoto studied behavior of fermions in the 5-dimensional KK monopole field and showed that no Rubakov effect occurs in this case. Yoshimura computed quantum effective action at finite temperatures in KK theories. At higher dimensions anomalous behavior of induced gravity was found, which may have a profound implication to cosmology. Sakamoto applied Nicolai mapping to supersymmetric theories.

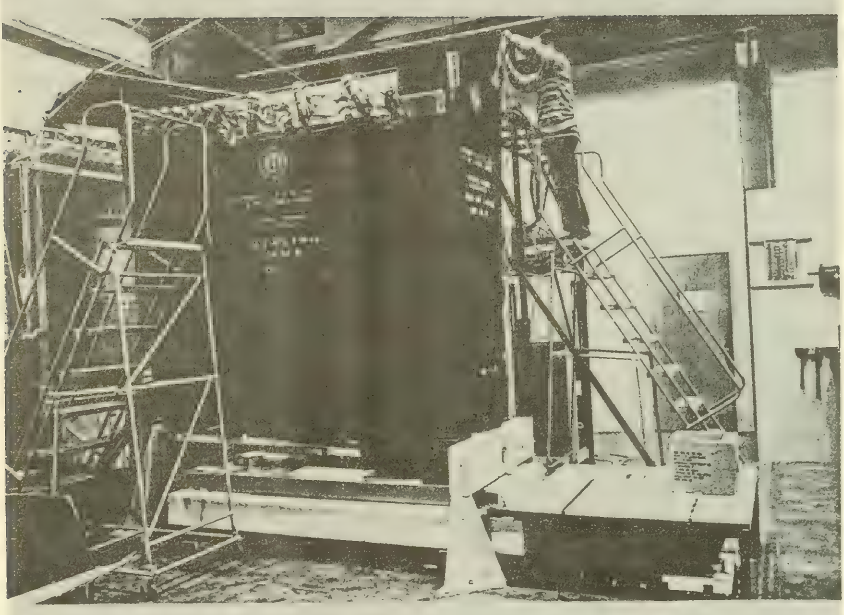
In application to cosmology, Sakagami investigated a termination of the phase transition in the new inflationary universe, caused by dissipative processes. Yoshimura, in collaboration with Takasugi and Fukugita, discussed gravitational collapse of a cloud made of the invisible axion which may provide the missing mass of the universe.

Yukawa are interested in subjects relating to statistical properties of finite systems. An important issue of the problem is how the statistical behavior sets in for an isolated, finite system. Detailed studies are made for: (1) Landau damping in the quantum Fermi liquid where the elementary excitation decays without collision term in the transport equation, (2) level statistics of the billiard problem for clarifying relation to the classical chaos, and (3) KNO scaling as the fractal.

Sakagami, together with Wadati, studied a correspondence between the classical soliton and its quantum field theory.

Most of these works have been published in about 17 preprints (KEK- TH series), and have been and will be printed in periodical journals.

International Collaboration



Central Hadron Calorimeter of the Colliding Detector Facility at Fermi National Accelerator Laboratory

The US/JAPAN Cooperation on high energy physics has been executed under the Implementing Arrangement between the U.S. Department of Energy and MONBUSHO of Japan on Cooperation in the Field of High Energy Physics, which was signed on November 11, 1979, at SLAC. The US/JAPAN Committee on High Energy Physics, consisting of six members from each side, has been held once a year in the U.S. and Japan alternately. The Fifth Meeting of the Committee was held on May 24-25, 1983 at Berkner Hall, Brookhaven National Laboratory. J. Leiss, Director of the Office of High Energy and Nuclear Physics of the US Department of Energy, and T. Nishikawa, Director General of KEK, were co-chairmen. Other members of the Committee who attended the Meeting were E. Hyde, L. Lederman, W. Panofsky, N. Samios, J. Sandweiss, K. Kusahara, T. Kitagaki, T. Fujii, G. Takeda, and K. Kikuchi.

In the opening remark, T. Nishikawa stated that the collaboration has been of high quality and expressed his desire to continue and strengthen this successful program, even beyond the period described in the agreement (1979-1988). He added that the most important event in the Japanese high energy physics program for the present and next five years is the construction of TRISTAN at KEK and that participation of US scientists in its physics program is most welcome. He also stated that, from the Japanese point of view, US/JAPAN Collaboration on a next generation international accelerator is the most practical and favorable among several cooperative possibilities, and suggested to start an exploration of the possibility of a cooperative effort leading to a very large accelerator facility.

The Committee agreed that the existence of TRISTAN as a frontier colliding accelerator would tend to strengthen and balance the US/JAPAN Cooperative Program through participation of U.S. scientists. The Committee also agreed that it was important and most timely to initiate a cooperative effort in the R&D and design for an eventual very large facility.

An informal meeting to propose a program of collaboration between the U.S. and Japan on accelerator R&D for the next five years was held on February 23-24, 1984, at KEK. G. Loew, SLAC, and T. Kitagaki were co-chairmen of the meeting. Other participants were R. Lundy (FNAL), C. Pellegrini (BNL), H. Hirabayashi, T. Kamei, Y. Kojima and J. Tanaka (KEK). It was generally agreed that the topics of mutual interest fall into three main categories: (1) Topics on which collaboration presently exists and should be continued, or for which an immediate need is mutually recognized, (2) Topics which relate to new accelerators such as a 20 TeV hadron collider or a 1 TeV electron-positron collider, and (3) Topics having to do with new methods of acceleration.

In FY 1983, 93 Japanese scientists participated in US/JAPAN joint activities at U.S. laboratories and 35 stayed in the U.S. more than six months.

Participation in the Electron-Positron Colliding Experiment (PEP-4) at SLAC-PEP and Development of New Detection and Data Handling Technology

Spokesman
JAPAN: T. Kamae, Univ. of Tokyo
UNITED STATES: D. R. Nygren, LBL, Univ. of California

Participating Groups
JAPAN: Univ. of Tokyo and INS (Univ. of Tokyo)
UNITED STATES: LBL (Univ. of California), UCLA, Yale, UC Riverside, Johns Hopkins and others.

The PEP-4 TPC detector is unique in that it can identify particles produced in hadronic jets. Charged particles are detected by the time projection chamber (TPC). The initial checkout of the detector was completed in the spring of 1982. This was followed in the fall of 1982 and the spring 1983 by the regular data taking runs, which allowed us to accumulate 29000 e^-e^- hadronic annihilation events (corresponding to an integrated luminosity of 77 pb^{-1}). We report here about performance of the two major detector components, TPC and the hexagonal calorimeter and physics results that have been completed in Japanese FY 1983.

The TPC identifies charged particles by the ionization loss (dE/dx). The momentum resolution is $(dP/P)^2 = (0.06)^2 + (0.035P)^2$ (P in GeV) in a 4 kG axial magnetic field. We have achieved the dE/dx resolution of about 4 %, which is almost the "Proposal" value. In the low momentum region, the pion, kaon and proton bands are well separated. Above 1 GeV/c the resolution is comparable to the differences in dE/dx for the various particle types. At 5 GeV/c, the separation is 3.8 s.d. (standard deviation) for pion-kaon, and 1.9 s.d. for kaon-proton (Fig.1).

The HEX consists of six modules located outside the magnet coil. Each module is 10 r.l. deep and contains 40 layers of a lead-fiberglass-aluminum laminate alternating with gas sampling layers with a Geiger mode discharge. Electromagnetic showers are reconstructed by radially-aligned half-degree wide channels in three stereo views. The typical energy and angular resolutions are 16 % and 8 mrad at 1 GeV/c, respectively.

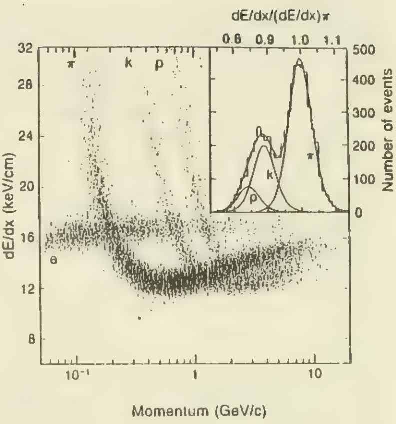


Fig. 1. dE/dx versus momentum for tracks inhadronic events.

We have measured the inclusive production cross sections and mean multiplicities of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ with very small systematic and statistical errors. The result shows that 10.7 ± 0.6 $\pi^{\pm}$, 1.35 ± 0.13 $K^{\pm}$ and 0.60 ± 0.08 p, $\bar{p}$ are contained in an annihilation event. Combining this particle identification capability and another unique feature of the TPC, the truly 3-dimensional tracking, we have measured the production cross sections of K^0, Λ, and Ξ particles. The production cross sections of ϕ's and K^{0*}s are also obtained for the first time at the present energy. There are 0.077 ± 0.020 ϕ's and 0.50 ± 0.15 K^0 per event in the range $0.075 < x < 0.55$. We studied charge weighted correlations in rapidity space and observed both short and long range strangeness compensation in K-K correlations. The K-π correlations due to heavy quark decays, and the proton-meson, proton-antiproton and $\Lambda - \bar{\Lambda}$ correlations are being studied now. We also have observed, for the first time, the polarization of the produced Λ's. Using photons detected by the HEX, the inclusive γ and π^0 cross sections were obtained. Figure 2 shows the invariant mass distribution for all photon pair combination. The fractions of the

total energy carried by photons and π^0's are 0.262 ± 0.025 and 0.209 ± 0.021, respectively.

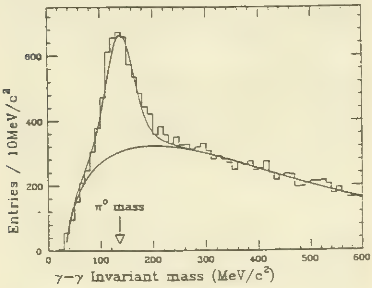


Fig. 2. The $\gamma - \gamma$ invariant mass spectrum.

The other major physics topic we have been concentrating on is the study of heavy (c and b) quark productions. Using the dE/dx measurement by the TPC and the electromagnetic shower detection in the HEX, we obtain a very clean sample of prompt electrons: We have rejected hadrons by a factor of 10000 or more. Using this sample, we have determined the semi-electronic branching fractions of c and b quarks as $(9.1 \pm 0.9 \pm 1.3)\%$ and $(11.0 \pm 1.8 \pm 1.0)\%$, respectively. The b quark fragmentation function peaks at high $z = E_{had} / E_{beam}$ with $<z_b> = 0.74 \pm 0.05 \pm 0.03$. From the measured forward-backward asymmetry in $e^+e^- \to q\bar{q}$, the axial couplings to the neutral current are determined to be $a_c = 2.3 \pm 1.4 \pm 1.0$ for the c quark and $a_b = -2.0 \pm 1.9 \pm 0.5$ for the b quark. These values are consistent with expectations of the standard electroweak theory. Prompt muons are identified by the muon detector. Using the prompt muons, we obtain the semi-muonic branching fractions of c and b quarks as $13.2 \pm 2.0\%$ and $7.2 \pm 1.5\%$, respectively. The muon spectra imply hard fragmentation functions for both c and b quarks, with $<z_c> = 0.55 \pm 0.08$ and $<z_b> = 0.83 \pm 0.06$, respectively. These results are in good agreement with the electron results.

The excellent particle identification by the TPC and the HEX has led us to the first observation of the F^* meson in the decay mode of $F^* \to F\gamma$. Of the four s-wave ground state charmed mesons only the F^* meson has not been established until now. The F meson is identified as a peak in the invariant mass distribution of $K^+ K^- \pi^\pm$ where all particle species are identified by the TPC. Photons are detected either by the HEX or by the TPC as e^+e^- pairs arising from photon conversion. Figure 3 (a) shows the distribution of the $KK\pi$ invariant mass. The thin solid line is for all $KK\pi$ with $z > 0.45$. We see an enhancement around the F mass region. Figure 3 (b) shows the distribution of $\Delta M = M(KK\pi\gamma) - M(KK\pi)$. The solid line is for the F region $(1.84 < M(KK\pi) < 2.08\text{GeV})$ and the dashed line is the average over the control regions $1.54 < M(KK\pi) < 1.78$ and $2.14 < M(KK\pi) < 2.38$ GeV). The measured ΔM spectrum for the F region

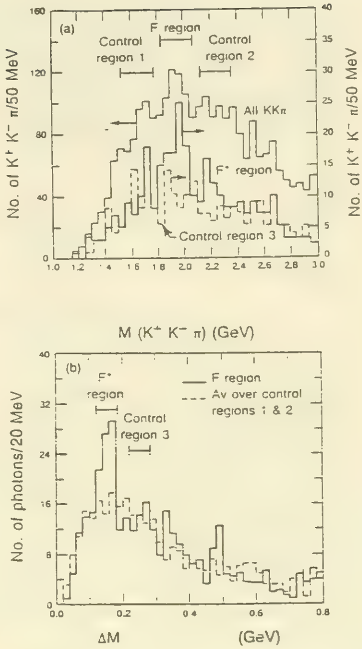


Fig. 3. a) Distribution of M(KKμ),
b) Distribution of $\Delta M = M(KK\pi\gamma)$-$M(KK\pi)$.

shows a clear peak, which gives the F^*-F mass difference, 154 ± 9 MeV. We have also obtained for the F mass, 1.952 ± 0.028 GeV, consistent with the measurement by the CLEO detector at CESR.

Proton-Antiproton Colliding Experiment (CDF) at FNAL

Spokesmen

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UNITED STATES:	L. M. Lederman, FNAL

Participating Groups

JAPAN:	Univ. of Tsukuba, KEK, INS (Univ. of Tokyo, Fukui Univ. and Saga Univ.)
UNITED STATES:	FNAL and many others from the U.S. and Europe.

Most of the CDF detector components including front end electronics are in the production stage. The data aquisition system has been designed and is being prototyped. With respect to the Japanese contributions, the scintillators and wavelength shifters for the 48 wedge modules are completed, a quarter of the end plug electromagnetic calorimeters has been built, and the superconducting solenoid has been constructed. The electromagnetic calorimeters are being studied and tested with cosmic rays and the pion and electron beams of Fermilab.

1) Endplug Electromagnetic Calorimeter

The endplug EM calorimeter consists of four 90° sectors of lead and resistive-tube MWPC sandwiches. The uniformity in sensitivity better than $\pm3\%$ (in σ) per plane, $\pm0.6\%$ for the electromagnetic energy measurement as estimated, has been achieved. The chambers are stacked with lead plates at Fermilab, and the calorimeter system is being tested at Fermilab M-bottom beam line.

2) Central Electromagnetic Calorimeter

The scintillators and wavelength shifters for the 48 modules have been produced and cut in Japan and sent to Fermilab. The assemble of the EM calorimeter modules is in progress by collaboration with an ANL group. Intensive efforts were put on improvement of the homogeneity of the calorimeter by putting correction reflector at the back of wavelength shifter. The overall homogeneity among equivalent towers are aimed to be better than 0.5 % in σ. The cosmic ray tests for the all assembled modules are being made at Fermilab, and extensive beam tests are in progress for typical modules in the NW beam line at Fermilab.

3) Vertex Time Projection Chamber

To reinforce the tracking detection and determine the vertex point, a TPC segmented into 14 cells along the beam axis has been designed. The R&D is under way by collaboration between Fermilab and the Japanese group.

The Basic characteristics were studied with a test chamber. As a read out system, Flash ADC CAMAC modules, which will be upgraded to FASTBUS modules, were built and used for the test.

4) Superconducting Solenoid

The construction of the superconducting solenoid by the Tsukuba group has been completed. The coil consists of an aluminum clad superconductive wire supported with an aluminum cylinder. Cooling-down is made by using liquid helium flow through the pipe running on the outer surface of the support cylinder. Mechanical safety was carefully checked in the design and the production procedure.

5) Software

The general scheme of the off-line analysis is being developed at Fermilab. The Japanese group worked among other things on simulation of the calorimeter modules by using the generation programs of jets, W and Z, heavy flavors and supersymmetric particles. It was demonstrated that by the fine granurality, a good magnetic field configuration and hermeticity of CDF a good electron and γ identification and the missing energy measurement can be achieved.

Lepton and Hadron Pair Production near Kinematic Limit (E605)

Spokesmen:

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Participating Groups

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UNITED STATES:	Coloumbia Univ., Fermilab., Stony Brook, Univ. of Wash-

ington

EUROPE: CERN, Sacley

E605 at FNAL is an international high energy physics collaboration among scientists from Japan, Europe and the United States, and aims to study of pair and single particle production at large masses and at large transverse momenta with high resolution and sensitivity for rare processes. The physics subjects relevant to this experiment are such as Drell-Yan process and its higher order processes, J/ψ, Υ, high P_T hadrons, vector mesons, Higgs particles production, K-factors, μ-e universality, etc.

The experiment was tuned up in spring of 1982 with primary beams of less than 10^{10} protons per pulse reduced due to background rates. The data taken over the first two weekends in June 1982 with Be, Cu and W targets contains a few million single hadrons with $P_t \geq 3.5$ GeV/c and a few thousand pairs with $M \geq 8$ GeV/c. These data showed expected performances of the detection system, so that the combination of the ring imaging Cherenkov counter and the calorimeter enable us to separate e, μ, π, K and P. The data were analyzed and the results on the A-dependence of single hadron production and particle ratios such as p/π^+, K^+/π^+ and K^-/π^- at large P_t region were obtained. Because our spectrometer has rather wide angular acceptance around 90° in the C.M. system, no angular dependence was observed for α.

A gain monitoring system utilizing a N_2 laser source with quartz fibers was installed in spring of 1983 and showed that it is capable to monitor gains of photomultiplier-tubes of the calorimeter with an accuracy of less than 1%. During summer of 1983, the magnet "SM0" was added in front of the "SM1" magnet, so as to reduce the neutral background coming from the target, and a scintillation hodoscope was also added at down stream of the calorimeter to provide a clean trigger for muon pairs.

Since last fall, TEVATRON II started to operate, the data were collected with the primary beams of 400 GeV/c and intensities of $2\sim4 \times 10^{11}$ protons per pulse in winter of 1984. The targets used in this run were LH_2, LD_2, Be, Cu, and W. Numbers of events were more than 2 millions for each targets, so that a large number of events with $P_T \geq 10$ GeV/c ($x_t \cong 0.75$) for single hadron and $m \geq 15$ GeV for dimuon are expected.

In this spring, it is expected to collect the data with 800 GeV/c insident beam with varieties of targets.

Study of Weak Decay Lifetimes of Neutrino Induced Particles in a Tagged Emulsion Spectrometer at FNAL (E531) and Measuring Charm and B Decays via Hadronic Production in a Tagged Emulsion Spectrometer (E653)

Spokesmen

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UNITED STATES: W. Reay, Ohio Univ.

Participating Groups

JAPAN: Kobe Univ., Okayama Univ., Osaka City Univ., Nagoya Univ., Science Education Institute of Osaka, Aichi Univ. of Education, Univ. of Tokyo and Yokohama National Univ.

UNITED STATES AND OTHER COUNTRIES: FNAL, Korea Univ., McGill Univ., Ohio State Univ., Univ. of Ottawa, Univ. of Toronto., Carnegie Mellon Univ. and Univ. of Oklahoma.

This collaboration was formed in 1977 to perform Fermilab Experiment 531, a search for neutrino induced charm decays using a hybrid emulsion spectrometer. A 1979 E531 exposure is fully published and analysis of the 1981 exposure is almost complete. A high-statistics study of hadro-production of charm and beauty at the Tevatron was approved in 1981 and equipment is being installed preparatory to a June 1984 test, and a data-collection run in the first half of 1985. The following is a report of resulting physics, current status and short-term plans for these efforts.

In the 1979 run of E531, twenty-five liters of emulsions furnished by Japan were exposed to a wide-band neutrino beam. Based on 45 found decays, production cross-sections and lifetimes were published for D^0, D^+, F^- and Λ_c^+ charmed particles. By 1980, the ability to observe visible decay lengths was seen to have applications beyond lifetimes — bounds were set on beauty production and $\nu_\mu \rightarrow \nu_\tau$ neutrino oscillations.

A 1981 run with 35 liters of emulsion has resulted in 100 additional found decays, analysis of which will be completed in calendar 1984. These data will be used to improve lifetimes, further establishing F and lower neutrino oscillation limits to 0.003 in $\sin^2 2\theta$ and 1.5 eV^2 in $\delta\ m^2$. Further, cross sections for directly observed charm will be comparable in quality to the higher-statistics indirect Dimuon results of others. Finally, bounds will be set ruling out all known sources for same-sign dimuons except D^0-mixing.

Fermilab Experiment 653 is a natural extension of these efforts. A new hybrid-emulsion spectrometer will be used to observe 15,000 charm and perhaps 200 beauty decays resulting from exposure of 100 liters of emulsion to 800 GeV protons. Charm and beauty lifetime measurements will be improved and searches will be made for new charm and beauty states. Emphasis will be placed on observing rare decay modes such as $F \rightarrow \tau \rightarrow X$, which together with beam dump experiments is needed for establishing the existence of the Tau neutrino. Finally, the large fraction of neutrino-induced same sign dimuons and the long B lifetime has heightened interest in D^0 and B^0 mixing, both of which will be measured in E653. If any mixing proves large, a new window could open for studying CP violation, a puzzle of twenty years standing.

Though at present we are 3-4 months behind schedule, the experiment is beginning to take shape. All magnets, toroids, and heavy steel are in position, and the emulsion target mover with computer controls has arrived from Japan. The rest of the equipment has been prototyped and is under construction. Pieces of each system are arriving preparatory to a June 1984 test in which the beam and subset of the spectrometer will be commissioned. A small emulsion exposure also is planned in order to exercise the world's largest emulsion pouring and processing facilities, now being constructed at Fermilab by Japanese and United States personnel. This exposure also will test the close connection between emulsion and electronic spectrometers essential if 10^5 events are to be scanned for dacays.

Finally, because of the low percentage yield of charm and beauty decays in hadronic interactions, a powerful muon detection system with on-line selection capability is being installed. About half of this muon system will be exercised in the June test.

Fortunately, slippages in accelerator scheduling have kept pace with delays in E653 construction. The experiment should be ready for a 40 liter exposure now commencing January, 1985. Two additional exposures of 40 liters each are planned for 1986 and 1987 with apparatus improved to overcome difficulties which may arise in the initial run.

A Measurement of the Elastic Scattering of Neutrinos and Protons (E734)

Spokesmen

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UNITED STATES:	D. H. White, BNL

Participating Groups

JAPAN:	KEK, Osaka Univ. and INS (Tokyo)
UNITED STATES:	BNL, Brown Univ., Univ. of Pennsylvania and State Univ. of N.Y. at Stony Brook

1) Data taking

We finished the data taking of approved 1500 hours successfully. The high repetition rate (1.2 seconds) and high intensity (1.3×10^{12} protons on target per burst (POT)) of the AGS provided us 4.3×10^{19} POT during August-December, 1983 run. Summary of the past data taking history is given in Table 1.

Table 1. Summary of data taking

	POT ($\times 10^{19}$)			# of Events	
Year	ν	ν	Detector	$\nu_\mu e$	$\nu_\mu e$
1981	.63	.05	1/2	–	–
1982	.99	.91	Full	51 ± 9*	44 ± 12
1983	1.52	2.77	Full	88	60
Total	2.40	3.68	–	140	100
1985	5.7**				

* Published
** Scheduled

Additional 1500 hours of running (corresponding to 5.7×10^{19} POT) has been approved and is scheduled 1985.

2) Detector

The neutrino detector at BNL built by the

collaboration between the U.S.A. and Japan, consists of 122 modules of main detector followed by the gamma-catcher, which is ten modules of liquid scintillator slabs with one radiation length of lead between each module. Following the gamma catcher is a magnetic spectrometer which aids in measuring ν_μ contamination by $\bar{\nu}_\mu$. Each module of the main detector has a calorimeter module of 4m × 4m, segmented into 16 cells vertically, 3 inches of thickness followed by two Proportional Drift Tubes (X,Y), 4m × 4m. Each PDT plane has 54 cells. Total weight of the detector is about 200 metric tons.

3) Analysis

3-1) $\nu_\mu e \rightarrow \nu_\mu e$

Clean signals were extracted from the neutrino data taken in 1982. The number of events collected over the energy region 210 < E < 2100 MeV was 51 ± 9 above a flat background of 25 ± 3 (mainly from $\nu N \rightarrow \nu N\pi^\circ$). The cross section was normalized relative to quasi elastic events and found to be $\tau(\nu_\mu e \rightarrow \nu_\mu e) = 1.60 \pm 0.29(\text{stat}) \pm 0.26(\text{sys}) \times E_\nu$ (GeV) $\times 10^{-42}\text{cm}^2$. Expected number of events of the entire data is given in Table 1.

3-2) $\bar{\nu}_\mu e \rightarrow \bar{\nu}_\mu e$

The analysis of the $\bar{\nu}_\mu e \rightarrow \bar{\nu}_\mu e$ reaction is going on in a similar manner as $\bar{\nu}_\mu e \rightarrow \bar{\nu}_\mu e$. An extra care is necessary to take account for smaller anti-neutrino flux, larger ν_μ contamination and larger backgrounds. Preliminary results as of February, 1984 on the data taken in 1982 is shown in Fig. 4.

After complete analysis on both $\nu_\mu e$ and $\bar{\nu}_\mu e$, we expect to obtain a precise value of $\sin^2\theta\omega$ ($\Delta\sin^2\theta\omega \cong 0.01 \sim 0.015$) by taking the ratio of the cross sections.

3-3) $\bar{\nu}_\mu p \rightarrow \bar{\nu}_\mu p$

Topology of the reaction is a single short track originating in the detector. Particle identification method based on dE/dx and range to separate protons from pions and muons has bean developed. Momentum transfer (θ^2) dependance of the crosssection is determined relative to small angle quasi-elastic process. The result is given in Fig. 5. It represents one tenth of all the data taken so far. The cross section can be used to determine a precise value of $\sin^2\theta\omega$ with given axial form factor mass, MA or vice versa.

3-4) $\bar{\nu}_e n \rightarrow e^- p$

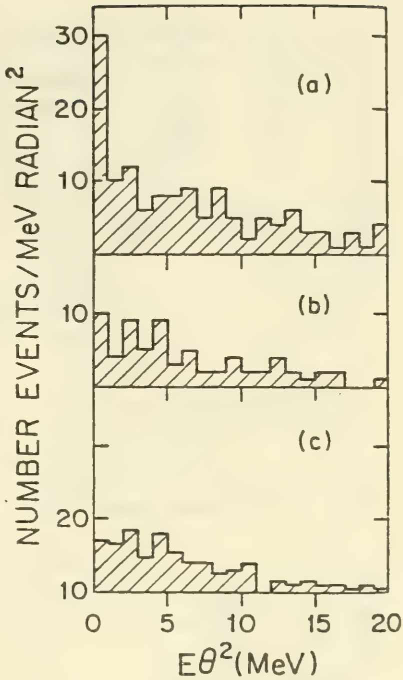

Fig. 4. Data of neutrino-electron scattering taken in 1982.

Using ν_e component in the dominant ν_μ beam the crosssection of inverse beta decay process has been determined. Then we compared its energy spectrum with the expectation as derived from both ν_μ quasi elastic data and calculation. We expect to derive a new limit ($2-4\times10^{-3}$) on the mixing angle of $\nu_\mu \rightarrow \nu_e$ oscillation (Fig. 6).

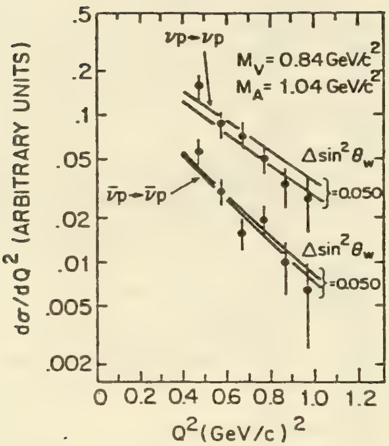

Fig. 5. Cross section of neutron-proton scattering.

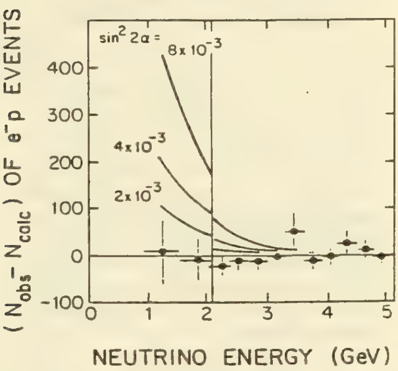

Fig. 6. Mixing angle of $\nu_\mu \to \nu_\mu$ oscillation vs. Neutrino energy.

Multi-Particle Production Experiment with LASS Facility at SLAC

Spokesmen

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UNITED STATES:	D. W. G. S. Leigh, SLAC

Participating Groups

JAPAN:	Nagoya Univ., KEK and INS (Univ. of Tokyo)
UNITED STATES:	SLAC and Cincinnati Univ.

With renewed charged tracking and particle ID devices in the LASS solenoid field, E135 data taking run with 11 GeV/c K^{+-} beam was completed at the end of May, 1982. The number of events reached to 150 million, which were logged on 2700 tapes in total. The sensitivity of the experiment is about 5.1 events/nb for K^-P process and 1.3 events/nb for K^+P process respectively.

Now production of data summary tapes (DSTs), updating the code itself, establishing the final calibration constants and the physics analysis routines (Monte-Carlo code, refitting routine etc.) are proceeding in parallel. DST production has been shared between Nagoya and SLAC, utilizing dedicated FACOM M200 system at HE-Lab at Nagoya and 9 systems of 168/E special processor farm at SLAC, and will be completed within a year. We have already have 350 DSTs by preliminary version of the code, which enable us to start physics analysis with fairly high statistics (400 events/μb).

The main interests of this experiment are categorised as: 1) Strange meson spectroscopy. K^* series, orbital and radial excitation; $K\pi$, $K\pi\pi$, $K\pi\pi\pi$ final states. 2) Hypercharge exchange processes. Spectroscopy of $s\bar{s}$ mesons; ϕ, ϕ^*, f', h', E.. , and nonstrange mesons. and 3) Hyperons. Cascades, Ω, Ω* etc.

Here we will briefly report the progress of each processes and present some of preliminary results.

1) Strange mesons

$K^-\pi^+$ elastic channel and $K^-\omega$, $K^-\eta$ final states have been studied so far. $K^0\pi^-$, $K^0\pi\pi$, $K^-\pi^+\pi^-$ channels are planned to be studied. Figure 7 shows $K^-\pi^+$ effective mass over all Jackson angle from 15 % of the experiment. Already three structures are apparent. In the previous study on $K^-\pi^+$ channel

(E132) that established 4^+ and radial excited states of K, we had holes in the acceptance at the high mass region and only two peaks are seen in the same plot. In E135 we have much improved acceptance in the wide and forward angular region. Now detailed angular analysis are on going and far improved results, especially finding spin 5 K^* and other underlying radial excited states are anticipated by full sample of this experiment. Besides the $K^-\pi^-$ elastic channel, effort to define the $K\omega$, $K\eta$ branching ratio by directly observing these final states of K^*, Q, L states is being tried.

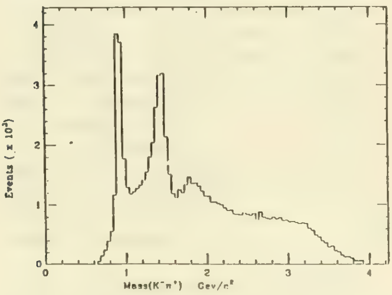

Fig. 7. Mass (K π^+) total events.

2) Hypercharge exchange processes

This channel is of special interests to survey $s\bar{s}$ mesons. K^+K^-, K^0K^0, $K^0K\pi$, $\eta\pi\pi$ channels are being studied now. As a typical example, Figure 8 shows K^0K^0 effective mass with Λ/Σ and Σ^* as recoil baryons. This channel involves two V^0 s, and only even spin object appears. Here we can see clear f' signal with only 5 % of the total data. We hope to find 4^+ $s\bar{s}$ meson (h') and get systematic knowledge on underlying $s\bar{s}$ states by K^- beam with the total data of the experiment. Also K^+K^- two body channel suggests some structures above 1.6 GeV, and seems to be quite promising. Study of K^0 $K\pi$ was just started.

3) Hyperons

11 GeV/c K^-P reaction is an abundant source of strange baryons. By high statistics of E135, many

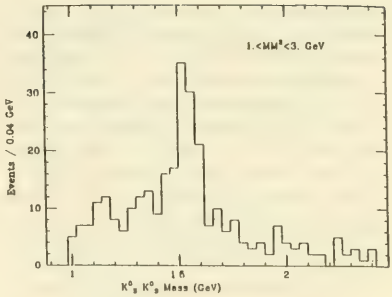

Fig. 8. K $\bar{p}$ K^0K^0 $\pm$ anything.

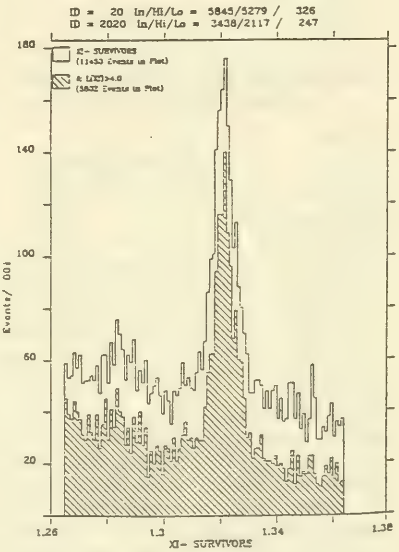

Fig. 9. Peak of Ξ^- (1321) seen in V^- topology events.

ambiguous Σ^*, Ξ^* will be confirmed and new states including Ω^* are expected to be seen in various final

states. Studies are being done in V^- topology (cascade) and ΛK final states. By refined vertex hunting algorithm, we can see clean Ξ^- (1321) from V^- topology events (Fig.9) by only 10 runs. Note that Ω^- has the same topology with K^- instead of π^-. As a byproduct of hypercharge exchange reaction study, ΛK^- and ΛK^* final states are studied. From a preliminary mass plot several Ξ^*s are seen in the ΛK^- channel, suggesting the possiblity to study strange baryons from various final states.

We briefly reviewed the present status of E135 by introducing typical examples. By the preliminary study on various channels, we are quite confident that LASS performs as good as expected. We expect to answer many outstanding questions on hadron spectroscopy by the data with high quality and extremely high statistics that we have never experienced before.

Bubble Chamber Experiments in 200 – 1000 GeV Energy Region at FNAL

Spokesmen

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Participating Groups

JAPAN: Tohoku, Tohoku Gakuin, Nara Women's

UNITED STATES and OTHER COUNTRIES: FNAL, MIT, Brown, Indiana, Tenessee, Oak Ridge NL, Tel Aviv, Technion, IHEP Beijing

1) E565/570 hadron experiment using the 30 inch BC hybrid system at 200 GeV energy.

90 K pictures were taken in Spring, 1981 and 675 K pictures in the spring run of 1982. Physics aims of this experiment are the investigation of high energy nuclear interactions, quark jets in the multiparticle production and others. A nuclear foil target system of Au, Ag and Mg was installed inside the 30 inch bubble chamber, and the analysis of high energy nuclear interaction showed interesting results on multiplicity distribution. The analysis of high multiplicity events in hydrogen is in progress.

2) E636 and E745 experiments at TEVATRON

E636 is a beam dump-prompt neutrino experiment at the TEVATRON. The primary physics aims are the direct proof of the existence of tau-neutrino and the study of the tau-neutrino mass. The Tohoku one meter Freon Bubble Chamber was specially designed and constructed for this experiment by Tohoku and IHI. The chamber construction was started in 1981. The operation test and training of people for operation were successfully made at Tokyo in Summer, 1983. The bubble chamber, interaction trigger counters and muon detecters are all at FNAL. The test of counters and assembling of the bubble chamber and superconducting coils on the chamber are going on in the new experimental hall, LAB-F, built for this experiment. The assembling will be completed by this summer and the operation of whole system will follow. The high resolution holography has been developed at Tohoku for finding short decays. The acheivement of the spatial resolution of 30 μm for the one meter chamber volume is one of the most important feature in this experiment. The whole holographic system with Nd-YAG laser will be assembled by the summer in LAB-F. The holographic reconstruction machines are also ready.

E745 is the mu-neutrino experiment at the TEVATRON using those detectors developed for E636. The E745 run is scheduled after December 1984 before E636. Therefore this will be an important engineering run for the beam dump experiment. The physics aims are the new studies of charmed particles and neutrino interactions in the high Q^2 region. The e, μ identification capability of the system and the high spatial resolution holography will bring interesting results on di-lepton events.

Photoproduction of Charm Particles in the SLAC Hybrid Facility

Spokesmen

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Participating Groups

JAPAN: Tohoku, KEK, Nara Women.

UNITED STATES and OTHER COUNTRIES: SLAC, UC-Berkeley, M.I.T., Tuft, Brown, Duke, Florida

State, ORNL, Tennessee, Imperial Coll., Rutherford Lab., Birmingham, Technion, Tel-Aviv and Weizman.

The BC 72/73/75 are 20 GeV photon experiment using the SLAC Hybrid Facility. Picture taking of the first part, BC 72/73, finished in March 1982 and the second part, BC 75, also finished in December 1983. The numbers of pictures in BC 72/73/75 for each run are as follows.

'80 Summer run	June-July	92 K pix.
'80 Fall run	November-December	444 K pix.
'81 Spring run	March-May	636 K pix.
'81 Fall run	October-December	806 K pix.
'82 Spring run	February-March	429 K pix.
'83 Spring run	March-June	611 K pix.
'83 Fall run	October-December	644 K pix.
Total		3,662 K pix.

The results on charm meson life from data up to '82, as is shown in Fig.10, are:

$$\tau(D^{\circ}) = 6.8^{+2.3}_{-1.8}\,(10^{-13}\text{sec}) \qquad (22 \text{ decays})$$

$$\tau(D^{\pm}) = 7.4^{+2.3}_{-2.0}\,(10^{-13}\text{sec}) \qquad (21 \text{ decays})$$

$$\tau(D^{\pm})/\tau(D^{\circ}) = 1.1^{+0.6}_{-0.3}$$

The cross section of charm photo-production at 20 GeV is:

$$\sigma(\text{charm}) = 56^{+24}_{-23} \text{ nb.}$$

The comparison of the cross section with other data is shown in Fig. 11. The data analysis of the BC75 run will be completed by the summer of 1984.

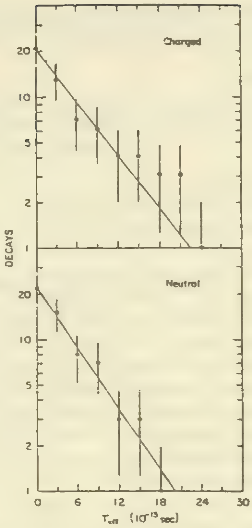


Fig. 10. Decay lifetime of charmed mesons.

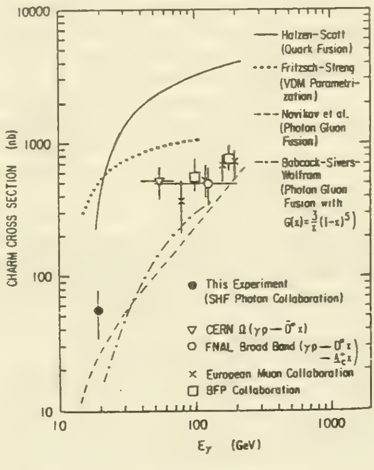


Fig. 11. Cross section of charm photo-production.

High Field Superconducting Dipole Magnet Development

Spokesmen

JAPAN:	H. Hirabayashi, KEK
UNITED STATES:	A. McIntuff, FNAL
	M. Suenaga, BNL

Participating Groups

JAPAN:	KEK, NRIM
UNITED STATES:	FNAL, BNL

1) High Field dipole magnet with NbTi/Cu cables

In this year a window frame dipole magnet with NbTi/Cu compacted strands cable was developed as the second model for 10 T dipoles. The monolithic cable is superior to the compacted strands cable from the view point of bearing stress. However it is difficult to obtain a high critical current density because of the limitation of reduction rate by an extrusion machine. The monolithic cable is also difficult to press the coil without damaging of insulators.

The rated current of the second dipole magnet was designed as 6,840 A from the current carrying capacity of the compacted strands. Each strand was checked at 1.8 K and confirmed that there was no degradation caused by the compaction. The cable was composed of 27 strands of NbTi/Cu. Each strand was 0.95 mm in the diameter. The cable could carry the current more than 7,900 A at 1.8 K and 11 T.

The dipole coil was composed of 8 double pancakes. The median 4 pancakes were bended at their ends to install a beam pipe and the other 4 pancakes at the top and bottom were made in race-track shapes as shown in Fig. 12.

The stress distribution in the coil and collar was calculated with a finite element analysis method and the prestress at room temperature was carefully measured. The collared coil was assembled in a cryostat in which the coil could be cooled to 1.8 K.

2) Nb_3Sn/Cu magnets and wire stabilization

Various tests on a single layer race-track dipole magnet, described in the previous report, were successfully carried out. Much data was obtained, such as the minimum quench energy (MQE), the characteristics of the normal zone propagation and the maximum temperature rise in the dipole. All of them

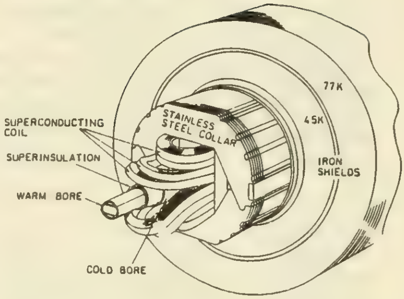


Fig. 12. Schematic structure of NbTi/Cu high field dipole at 1.8 K.

showed the technical feasibility and limit of Nb_3Sn/Cu magnets for the accelerators.

An attempt was made to fabricate a double shell dipole magnet with the same technique as in the race-track dipole magnet. The bronze-processed Nb_3Sn/Cu monolithic cable was keystoned in its cross section to make shell type winding easy. A double shell dipole magnet, having an I.D. of 132 mm and a length of 600 mm, was assembled in stainless steel collar laminations.

Besides the development on Nb_3Sn/Cu dipole magnets, basic studies on Nb_3Sn/Cu wire continued. For instance, the influence of stabilizing copper on the quench characteristics of Nb_3Sn/Cu wires was studied in detail. Measurements of the MQE in the bronze-processed wires showed that the optimum cross-sectional area of stabilizing copper is around 40%. In the case of good cooling, the MQE for Nb_3Sn/Cu wire at 10 T was almost the same as that for NbTi/Cu wire at 5 T. However, in the case of poor cooling the MQE for Nb_3Sn/Cu wire was approximately a factor of 3 greater than that for NbTi/Cu wire. There was a clear correlation between the MQE and the quench propagation velocity of the wire; the wire, having a large MQE, always had a low quench propagation velocity.

Development of Superconducting Rf Cavity

Spokesmen
JAPAN: Y. Kojima, KEK
UNITED STATES: G. Loew, SLAC
M. Tigner, Cornell

Participating Groups
JAPAN: KEK
UNITED STATES: SLAC, Cornell

A three-cell 500 MHz niobium structure (Fig. 13) has been built and tested. The shape of each cell and the technique of fabrication and surface treatment are similar to those of single spherical cells tested before.

The structure has an input coupler on the center cell, two higher mode couplers on each end cell and a mechanical tuning system. Before assembled to the three-cell structure, each cell was tested as a single cell and the location of surface defect which causes the quenching was detected by observing a temperature map of the surface. After mechanically removing the defect and re-treated the surface, Q_o at lower field and E_{acc}^{max} for each cell were upgraded to $\sim 3 \times 10^9$ and $4.8 \sim 5.7$ MV/m at 4.2 K.

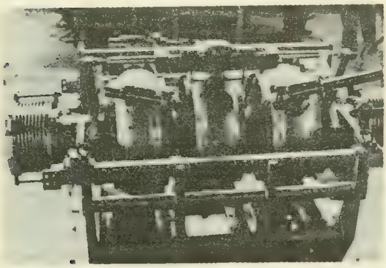


Fig. 13. A three-cell 500 MHz structure.

The structure was at first tested in a vertical cryostat without all couplers. Q_o at lower field was 1.3×10^9 and E_{acc} reached 5.2 MV/m without quenching. Due to the shortage of rf power, measurements at a higher field was not performed.

The structure was assembled with all couplers in a horizontal cryostat and installed in the TRISTAN accumulation ring. The beam test is planned to take place in May 1984.

High Power Klystron Development

Spokesman
JAPAN: J. Tanaka, KEK
UNITED STATES: G. T. Konrad, SLAC

This is the report on the 120 MW klystron research and development. FY 1983 is the last year of this three year R&D program. Although the first experimental klystron was completed at the end of FY 1982, a vacuum leak was founded at the weld joint of the klystron body and the test could not be performed. Some attempts to seal the leak were unsuccessful. After several weld joints were redesigned so as to reduce the stress at the joints during tube bake out, the first klystron was rebuilt and completed in June, 1983. The best performance obtained on the first klystron by the end of December, 1983 is listed up in Table 2.

Table 2.

	achieved	design
Beam voltage (KV)	475	450
Perveance (μp)	1.84	2.00
Peak beam current (A)	598	600
Frequency (MHz)	2856	2856
Peak power output (MW)	122	150
Pulse repetition rate (pps)	60	180
RF pulse width (μs)	1.0	1.0
Efficiency (%)	43	55
Gain (dB)	45	50

The output power was stable and no diode oscillation was observed at any voltage. The pulse shape was clean at and above saturation of the input rf power. Although output power of the first klystron was over 120 MW, it could not satisfy the design values completely. Consequently, the second klystron was planned to be finished by the end of May, 1984. However, because the development of 50 MW klystron for SLC program has priority at SLAC, the completion of the second klystron is postponed and will not be in test before the end of September, 1984. The principal

matter to be improved in the second klystron is

1. 2π-mode double output cavity
2. Standard XK-5 window without matching posts
3. A polished focus electrode
4. Correction of the perveance

Research and Development Project on Collider Detectors.

Spokesmen:

JAPAN:	K. Takahashi, KEK
UNITED STATES:	J. Ballam, SLAC
	P. Koehler, FNAL
	H. Gordon, BNL

Participating Groups

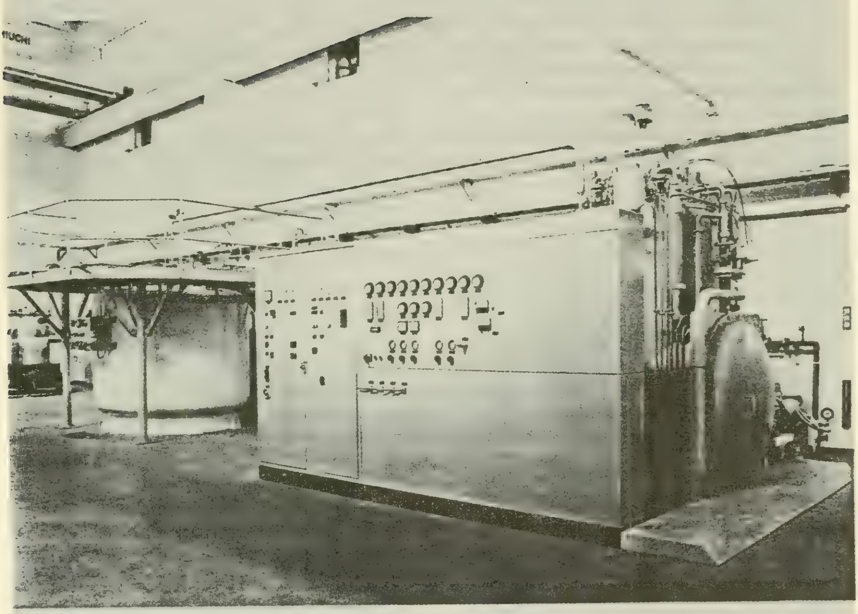
JAPAN:	KEK, Hiroshima Univ., Nagoya Univ., Nara Woman's University
UNITED STATES:	BNL, FNAL, SLAC, Princeton Univ., Univ. of Rochester

The project of the detector research and development (R&D) has been undertaken since 1982, at FNAL, SLAC and KEK, and also at BNL from 1983. The items chosen are those that are closely related to the technology in high energy e^+e^- colliders and are interesting to the physicists in both Japan and the U.S. with an understanding of important application of the outcomes to the experiments to be carried out at TRISTAN as well as at the SLC and the Tevatron collider. The project has since then gradually received more attention and interest with a hope for possible usage of new techniques in the future experiments. The items that have been carried out during these two years, are as follows;

1) Electro-Magnetic (E-M) calorimeter development (SLAC/KEK),
2) A planar spark counter as a good TOF counter and for a possible use as an E-M calorimeter (SLAC/KEK),
3) BGO crystal development (SLAC/KEK),
4) Development of a precision vertex detector by using CCD-chips and related technology (SLAC/KEK),
5) Development of FASTBUS technics in collider experiments (FNAL/KEK) and 6) Transition Radiation Detector Development for electron identifier (BNL/KEK).

Following the various fruitful results and achievement obtained in the Japaneses FY-1982, more extensive efforts have been made during the JFY-1983, with an addition of the transition radiation detector, being carried out at BNL and KEK. A new world-record value of time resolution in the TOF use of the planar spark counter (PSC), a very excellent quality in resolution of a lead glass (SF6) Cherenkov counter as an E-M calorimeter, and a very good progress in developing new Cherenkov glasses and BGO crystals are, among other things, the highlights in the various developments made in the JFY-1983. Some of these results are published elsewhere.

Engineering Research and Scientific Support Department



The new helium liquefier (Sulzer, TCF200) has been installed in the new building of the low temperature group

The Engineering Research and Scientific Support Department consists of four groups, i.e., Data Handling, Low Temperature, Radiation and Safety Control, and Mechanical Engineering (Work Shop). Radiation and Safety Control Group has a subgroup, Chemical Safety Group. The proper staff members of the Department are twenty-one scientists. Thirty technicians from the Technical Service Department are incorporated with them.

The Data Handling Group is responsible for the maintenance and operation of the central computer system, HITAC M-200H × 3 and L-340, the latter is for business services and safety control. As increasing demand of the data processing is expected for the experiments of TRISTAN which will start in 1986, the next central computer system is being discussed.

The Low Temperature Group operates two liquid helium supply systems and their recovery systems. The liquefiers supplied 88,000 litres of liquid helium during FY 1983. A new liquefier has been installed and the results of test run showed the liquefaction rate of 300 ℓ/h.

The Radiation and Safety Control Group is responsible for radiation security of the laboratory. In addition to routine works, the group is engaged in construction of the radiation protection system around the TRISTAN accelerator complex. The Chemical Safety subgroup is responsible for monitoring and treatment of waste fluid. A new treatment plant of waste fluid and a new chemical laboratory have been completed in FY 1983.

The Work Shop is undertaking some new kind of jobs, such as development of measuring machine for surface mirrors of the Photon Factory, the mechanical design of detectors for the TRISTAN and development of superconducting magnets.

DATA HANDLING

The present third-term central computer system in KEK installed on September 1, 1981, consists of loosely coupled three M-200H's. The system has 40 mega-byte main memory, 15 giga-byte disk file, and 35 giga-byte mass storage system and was delivered by HITACHI Co., Ltd.

The system has been operated satisfactorily using KEKNET (an on-line network system which is able to connect with 16 terminal computers) and KEKOPEN (a center batch processing system used in a cafeteria style). The system has continuously run in a cycle of two weeks in accordance with the operation of 12-GeV proton synchrotron.

Not only the system has processed a lot of jobs to analyze data generated from physics experiment using the 12 GeV proton synchrotron and the booster facilities but also it has done test run for control of TRISTAN accumulator ring and computed data for the research and development of the TRISTAN project.

And so the Scientific Advisory Committee for Computer has researched and estimated the need of processing data in two or three years as in the following: (those are estimated values in case of processing with M-200H system.)

1) physics experiment with 12-GeV proton synchrotron: 8,000 ~ 10,000 hours
2) experiment with booster facilities: ~ 6,000 hours
3) control of TRISTAN accelerator: ~ 3,000 hours
4) theoretical calculation: ~ 10,000 hours
5) study and maintenance of computer system: ~ 500 hours

As the result of those research, the Scientific Advisory Committee for Computer has estimated that the next fourth-term central computer system will have necessarily 1.5 ~ 2 times of data processing power than present one. And also the Committee has planned especially to install the vector processor for theoretical calculation and so on.

The committee has decided to introduce the computer system consisting of loosely coupled three computers, HITAC M-280D with 32 mega-byte main memory, HITAC M-280H with 16 mega-byte main memory and HITAC S-810/10 with 128 mega-byte main memory.

On the other hand, the computer system for TRISTAN project has been planned and researched by the Scientific Advisory Committee for Computer. Its scale will be as large as the fourth-term central com-

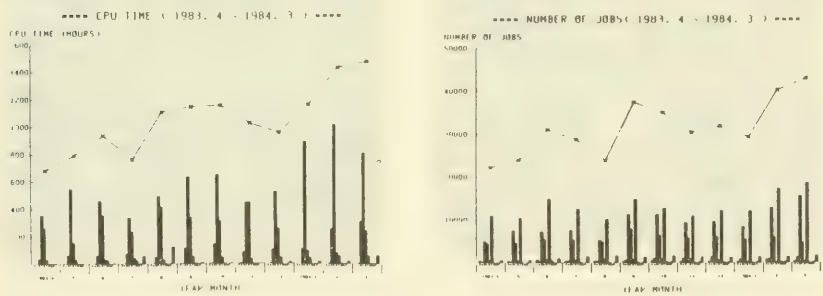


Fig. 1. The number of monthly processed jobs and used CPU time.

puter system with a large capacity of file, for example, 100,000 volumes of 6,250 bpi magnetic tape.

The total of processed jobs and used CPU time in this fiscal year were 350,547 jobs and 12,633 hours in three CPUs and distributed as follows:

	Job	CPU time
Accelerator Department	9.9 %	4.2 %
Physics Department	29.3 %	36.6 %
Eng. Res. & Sci. Support Department	9.6 %	1.7 %
Photon Factory	0.2 %	0.1 %
Booster Utilization Facility	2.9 %	1.1 %
Physics Experiments	48.1 %	56.3 %

The numbers of monthly processed jobs and used CPU time are shown in Fig. 1. Figure 2 shows turn around time in each month.

A KEK office computer network system has been installed for office business of the research and administration departments and has run from this fiscal year. We have used this local network system for the following jobs:

1) improvement of control and logging system for access to many radiation controlled areas by identification cards,
2) the administration system of the accommodations for researchers,
3) process of business services in the department offices.

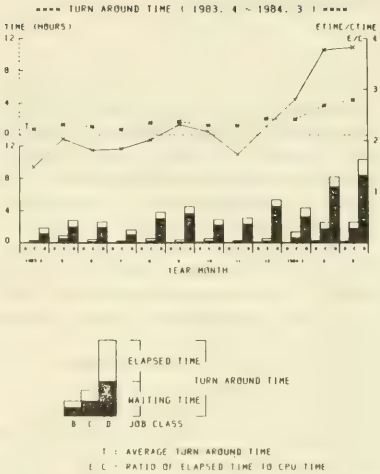


Fig. 2. The status of monthly turn-around time.

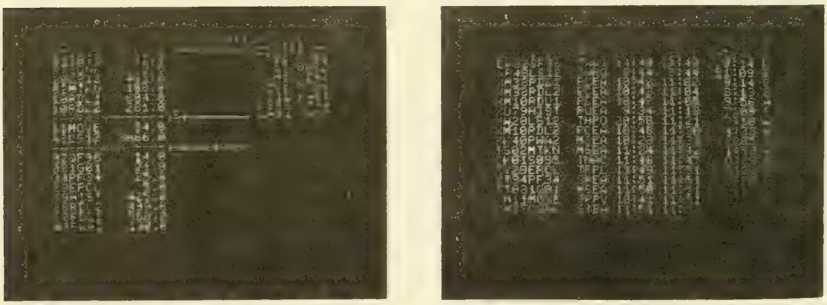


Fig. 3. The example of the display of running jobs status.

At present, this local network system is being scaled up in functions by its working group.

In addition to the operation of the computer system, Data Handling Group is working for the followings;

1) improvement and maintenance of the system softwares and the library programs,
2) collaboration with other research departments on design studies of data acquisition system for physics experiments and of control system for the accelerator in the TRISTAN project,
3) research and development of programs used by the Work Shop,
4) research and development of automatic information transfer system by telephone which will be used to call many persons automatically for transfering information,
5) research and development of local information network system in KEK that is an easy information-transfer system using a word processor and CATV,
6) conversion and tentative run of the Newlib and other useful programs.

LOW TEMPERATURE

Helium Liquefier

The central cryogenic facility supplies liquid nitrogen and liquid helium to research groups in the laboratory. The helium liquefier (Sulzer, Model HeL 55-2G) has been running throughout the year to produce liquid helium about 60,000 ℓ. The liquefier has been operated regularly since its installation in 1973. Now it reaches a time of careful maintenance and operation for a stable production of liquid, while the consumption increased considerably in the last few years. We introduce a new helium liquefier to overcome these situations in this fiscal year. We will be able to supply a sufficient amount of liquid helium with these two liquefiers to many users in the laboratory.

Users and their consumptions are summarized in Table 1. Here, losses in handling of liquid such as transfer and storage are not included. High energy physics groups continued the researches, a study on atomic hydrogen at very low temperature and R&D studies of the TRISTAN detectors. Groups of Booster Utilization Facility extended their studies on the polarization of epithermal neutron beam, the ultracold neutron, and the μ-meson experiments. A superconducting wiggler magnet started the regular operation in Photon Factory, which required a considerable amount of liquid helium.

Table 1. Amount of liquid helium used

Users	Amount
High Energy Physics	6,735 ℓ
Booster Facility	17,656 ℓ
Photon Facotry	12,207 ℓ
Others	1,490 ℓ
Total	38,088 ℓ

Recovery rate of helium gas maintained about 90 % of the supplied helium. There has been no problem on the purity of the recovered gas. One of the branch station of the gas recovery system was moved from the assembly hall for 12 GeV PS expriments to the new assembly hall for TRISTAN. Though the gas processing rate is unchanged, the gas storage capacity increased from 140 Nm^3 to 1,000 Nm^3, which allows the experiments with large systems in the hall.

The new helium liquefier (Sulzer, TCF200) has been installed in the new building of the low temperature group. A screw type compressor (MYCOM 2520C) is employed. We paid the special cautions in

its installation to avoid the influences of compressor noise and vibration in the environment. A liquid helium storage vessel, whose capacity is 3,000 ℓ, is connected to the liquefier with a long transfer tube. A monitor of the whole system is placed in an operating room. Owing to a large capacity of the compressor (2,800 Nm^3 /h) and a refined liquefier design, the system showed an excellent performance in a test run. The liquefaction rate reached 300 ℓ/h, which is almost the ideal value of this system.

Refrigerator/Liquefier

The helium refrigerator/liquefier system ("BOC Turbocool 100", capacity 400 W at 4.4 K or 110 ℓ/hr) has been operated without any trouble for cooling the superconducting RF cavity and the superconducting magnets. The liquid helium supplies for SC manget and SC RF cavity are shown in Table 2.

Table 2. Liquid helium usage

Users	Amount
SC Gavity	19,600 ℓ
SC Magnet	2,500 ℓ
Others	5,970 ℓ
Total	28,070 ℓ

On January, 1984, this helium refrigerator/liquefier system has moved in AR east building for cooling the superconducting RF accelerator cavity which was installed in AR to accelerate the electron beam. Figure 4 shows the flow diagram of the superconducting RF cavity cooling system.

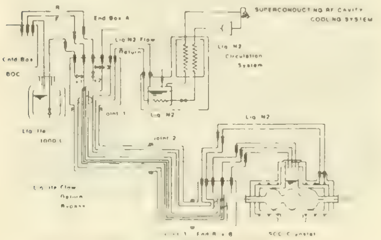


Fig. 4. Superconducting RF cavity cooling system.

Research on gravitational wave detection

(KEK, the University of Tokyo, Tokyo Observatory Collaboration)

A research on the gravitational wave detection from a pulser started after a few preliminary arrangements in the last years. Investigations on material, fabrication technique and performance of antennas were carried out on models. A 310 mmφ torsional type antenna was machined from an extruded 5056 aluminum alloy, and confirmed an excellent dynamical character at liquid helium temperature.

A new 500 mmφ antenna has been also machined from an ingot of the same alloy in Work Shop (Fig. 5). Its quality factor is a little lower than the former one, but the dynamical character is satisfactory. Each part of a vibration isolation system has been prepared. An optical observation of the Crab pulser was carried out by the telescope at Okayama Observatory to measure an accurate pulser period at present.

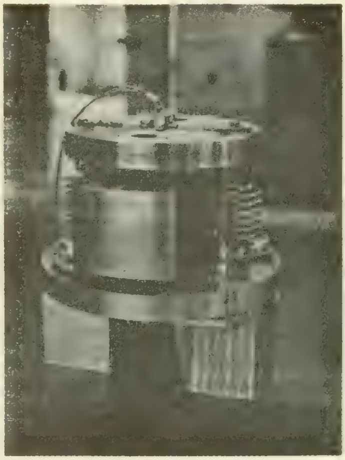


Fig. 5. A 500 mmφ gravitational wave antenna with a part of the vibration isolation system. It is machined from a single block of 5056 aluminum alloy. Two masses above and below a central fin make a torsional oscillation about a thin axis perpendicular to the fin. The quality factor (Q value) is 2.2 × 10^7 at 4.2 K. Four electrodes are mounted on the fin as the transducers. Two spirings form the last stage of the vibration isolation system which will attenuates the mechanical vibration to 260 dB. They are made of SUS316L and show an excellent performance at liquid helium temperature.

RADIATION AND SAFETY CONTROL

The Division of Radiation and Safety Control is composed of two groups, one for radiation safety and the other for chemical safety. At the end of March 1984, the division consists of 8 scientists, 4 technicians and 1.5 secretaries. Six scientists and 3 technicians are engaged in radiation safety works and one and one in chemical safety.

A building mainly for chemistry safety controls was built and set in use early autumn 1983.

Main incidents of the year to the division are summarized in Table 3.

Radiation Safety Group

The group is engaged in radiation security of the laboratory. Radiation safety supervisor is responsible for all radiation facilities in KEK, which include Particle Radiation Medical Science Center (PARMS) of the University of Tsukuba. Radiation safety supervisor and members of the main (KEK) radiation control office are composed of members of the group (Fig. 6).

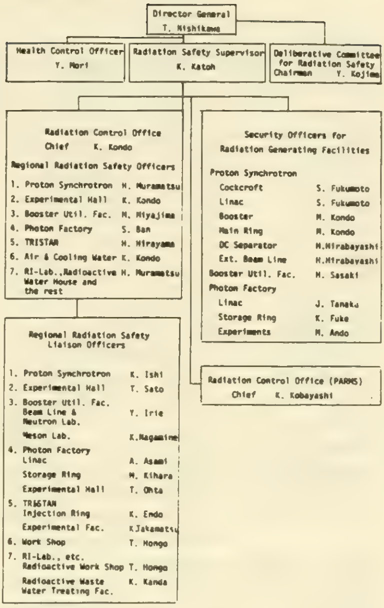


Fig. 6. Organization for radiation safety control.

Table 3. Record of main events in the Division of Radiation and Safety Controls in FY 1983

April	1	Renewal of deliberative committee for radiation safety due to expiration of tenure. Also, partial renewal of security officers for radiation treating facilities. Shin-ichi Takahara joined the Radiation Group as a member (Technician).
May	9	Regular training of radiation workers
June	3	Applying to Science and Technology Agency (STA) for using Injection Ring of TRISTAN, etc. as radiation facilities
July	5–6	Taking the legal regular examination of whole radiation treating facilities in KEK by Radiation Safety Technology Center (RSTC)
July	20	Applying to STA for partial changes in setting up of radiation controlled areas of BSF and related access controls
July	28	Application of June 3 was approved.
August		Building for chemistry safety controls was completed.
September	6	Application of July 20 was approved. Related construction works started.
October	1	Regional unification of radiation controlled areas was revised by chance of taking in the TRISTAN facility.
October	18	Completion examination of TRISTAN injection ring
October	19	Start to use TRISTAN injection ring
October	20	Applying to STA for using 10 kg of metal thosium in Counter Experimental Hall
November	28	Application of October 20 was approved.
January	26	Deliberative Committee for Radiation Safety, unusual was found among exposure records of radiation workers of PARMS.
February	24	Division's seminar by Dr. N. Ishiwatari (JAERI) on Countermeasures of Radiation Safety for Using Uranium as Target

Table 4. Statistics of exposure of staff members (1) and users (2)

(1) Staff members

Distribution*	Accel. Dept.	Physics Dept.	Sci. Supp. Eng. Res. Dept.	Admin. Dept.	Booster Util. Facility	Photon Factory	Total
Undetectable	52	48	30	73	1	49	253
10 – 40	24	10	3	10	1	13	61
40 – 100	6	6	4		1	2	19
100 – 200	7	9	3		4		23
200 – 300	2	2	1		2	1	8
300 – 400	4	1			2		7
400 – 500	1	1					2
500 – 600	3						3
600 – 700	2						2
700 – 800							
800 – 900			1				1
900 – 1000							
1000 – 1500		1					1
1500 – 2000	1						1
2000 – 2500							
Accumulated Dose**							
(γ)	8.43	2.65	1.03	0.16	1.84	0.56	14.67
(η)		1.41	0.77		0.04		2.22
Total	8.43	4.06	1.80	0.16	1.88	0.56	16.89
Average Annual Dose***	83	52	43	2	171	9	44

(2) Visitors (Users and Businessmen concerned)

Distribution*	Proton Synchrotron	Booster Util. Facility	Photon Factory	Buinessmen Concerned
Undetectable	130	124	476	349
10 – 40	20	23	25	27
40 – 100	24	2		13
100 – 200	22	3		10
200 – 300	12	1		3
300 – 400	5			2
400 – 500	2			1
500 – 600	2			
600 – 700				
700 – 800				
800 – 900				
900 – 1000	1			
Total	218	153	501	405
Accumulated Dose**				
(γ)	0.71	0.59	0.47	4.18
(η)	11.70	0.46	0.00	0.46
Total	12.41	1.05	0.47	4.64
Average Annual Dose***	57	7	1	12

* A – B means A < reading < B in mrem or 10 μSv
** in man-rem or person-cSv
*** in mrem or 10 μSv

Routine works include monitoring of radiation levels in and around radiation facilities, radioactivity in releasing air and water from the facilities, personnel exposures; access controls to the radiation controlled areas; managements of radioactive materials (radioisotopes, checking sources, nuclear fuel materials and radioactive waste); operation and maintenance of monitoring systems; RI laboratories, plants for treating radioactive waste water, equipments for access controls; calibration of detectors and training of radiation workers. In addition to these, R & D works such as radiation shielding calculations, designing works of new projects, studies on countermeasures for decreasing personal exposure, induced activities, radiation damages and so on, have been done mostly assertively but occasionally in response to requests. Details of the administration works made in this year will be published separately as a KEK internal report.

Exposure Records

Number of the radiation workers and semi-radiation workers at the end of the year were 1,986 (15.7 % up) and 264 (3.9 % up). Number of film badges issued was 7,776. The numbers of records whose values were over 40 mrem (0.4 mSv) and 100 mrem (1.0 mSv) were 231 and 88, respectively. The maximum of the monthly was 500 mrem (5.00 mSv) and the one of the annual was 1.55 rem (15.5 mSv). Table 4 and 5 are summaries of statistics of the exposure control works to individuals. Accumulated dose for workers from outside firms is 5.95 man·rem for γ and 12.62 man·rem for neutron, respectively.

Table 5. Numbers of radiation workers (1983 FY)

	Radiation Workers	Semi-Radiation Workers	Total
Staff	297	65	362
Graduate Student	13	–	13
Visiting Collaborator	15	–	15
Visiting Experimenter			
PS, TRISTAN	235	–	235
BSF	178	–	178
PF	624	–	624
Businessmen Concerned	624	154	778
Total	1,986	264	2,250

Chemical Safety Group

Chemical safety control system has been established in this year by construction of new buildings of chemistry laboratory and chemical storage, and by installation of new treatment plant for waste liquids. Chemistry laboratory contains test rooms for analyzing waste effluents, a clean room for ultratrace analysis, chemical experimental rooms for users and a dark room for developing films.

Waste liquid treatment plant was completed to cope with the great increase in amount and variety of waste liquids, on the decision of Deliberative Committee on Waste Treatment Safety. The treatment system consists of five main processes and its flow is shown in a simplified schematic in Fig. 7. Organic waste liquids are atomized with a rotary burner and burned up in the furnace. Heavy metals are removed from wastes by ferrite precipitation and chelating resin adsorption. Fluoride is removed by calcium fluoride precipitation and activated alumina adsorption. Cyanide is decomposed by the alkaline chlorine method. In addition to these ones, hydrolysis process is also included for a large amount of washing effluent.

The routine works have been carried out without the serious trouble with an aid of seven technicians from an outside firm. Monitoring of waste effluent quality was done by chemical analysis of 170 samples collected periodically at the various facilities. The amounts of the treated wastes are summarized in Table 6.

Table 6. Total of treated waste liquids

Organic	4.0 m^3
Inorganic	1.3 m^3
Washing effluent	277 m^3
RI effluent	6582 m^3

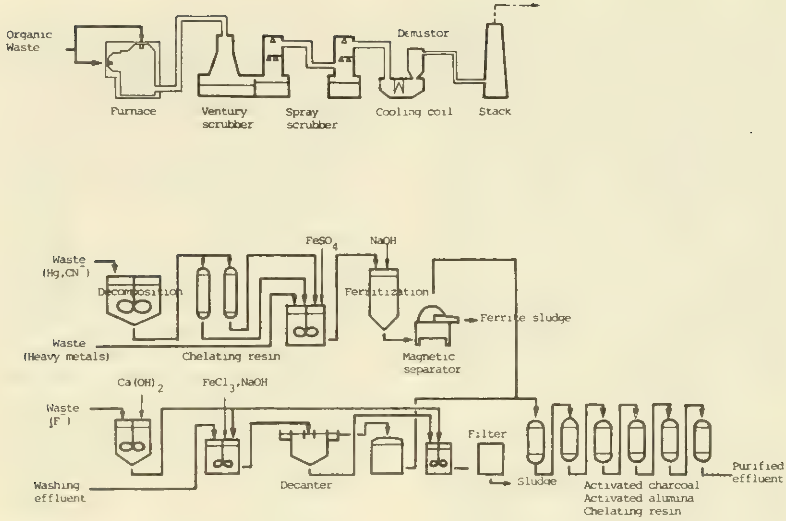


Fig. 7. Treatment system of waste liquid.

WORK SHOP

The Work Shop is responsible for designing and manufacturing of various specific instruments which are requested from each department and user's groups. The Work Shop includes the following buildings.

Building	Area	Completed
No. 1 Work Shop	560 m²	1970
Work Shop for radioactive instruments	40 m²	1977
No. 2 Work Shop	900 m²	1982
Precise measuring room	216 m²	1982

An engineer and fifteen technicians are currently engaged in the Work Shop. The engineer is in charge of operating the Work Shop and conducting research and development. The technicians are organized into the groups of development, design, machining and welding.

Major subjects of technical development in 1983 are:

1. Superconducting Magnets. A full size 5-Tesla dipole magnet (SD-TA-3100) and a model quadrupole magnet have been built. Liquid helium

transfer line has been built and showed a good performance.

2. Precise spherical surface measuring machine. This machine is to be used for the measurement of the curvature of concaved mirror for the Photon Factory.
3. Development of welding technique. Electron beam welding technique of two different metals has been developed.
4. Detector development for the TRISTAN experiments. The Work Shop is collaborating for design and development of the detectors for VENUS and TOPAZ groups.

In Table 7 are summarized jobs ordered to the Work Shop in FY 1983. Number of items for the jobs was 550. In Table 8 and 9 are given the lists for machines equipped in the Work Shop. Some of the instruments developed in FY 1983 are shown in the pictures (Fig. 8 and Fig. 9).

Table 7. Summary of jobs

Users	Hours (h)	Fractional Hours (%)
Accelerator dept.	5,172	15.9
Physics dept.	2,960	9.0
E.R.S.S. dept.*	1,575	5.0
Photon Factory	5,095	15,6
B.S.F.**	1,118	3.4
Experiments	1,465	4.5
Tristan	15,194	46.6
Total	32,579	100.0

* Engineering Research and Scientific Support Department
** Booster Synchrotron Utilization Facility

Table 8. List of machines (Work Shop for radioactive instruments)

Machines	No.
Lathe	1
Milling machine	1
Drilling machine	1
Welding machine	1
Sawing machine	1
Toolgrinding machine	1

Table 9. List of machines (Work Shop No. 1, No. 2 and precise measuring room)

Machines	No.	Remarks
Lathe	10	includes a 1.5 m type face lathe and a computer numerical controlled lathe
Milling machine	6	includes 2 computer numerical controlled milling machines
Machining center	1	vertical type, x-1300, y-800, z-650
Planomiller	1	stroke 2.5 m
Shaper	1	
Grinding machine	2	a surface grinder and a cylindrical grinder
Drilling machine	7	
Electron beam welding machine	1	6 KW (150 KV × 40 mA)
Electron discharge machine	1	
Wirecut electron discharge machine	1	300m × 400 × 120t (mm)
Welding machine	7	
Fusion welding machine	1	
Tool grinder	5	
Sculpt machine	1	
Press brake	1	8t × 2000 (iron)
Sawing machine	1	
Electric furnace	1	1200°C
Universal measuring microscope	1	accuracy ±0.5 μm
Three dimensions measuring machine	1	x-1500, y-800, z-650
Surface tester	2	5×10^4 and 1×10^6
Electric micrometer	2	
Projector	1	
Leak detector	1	

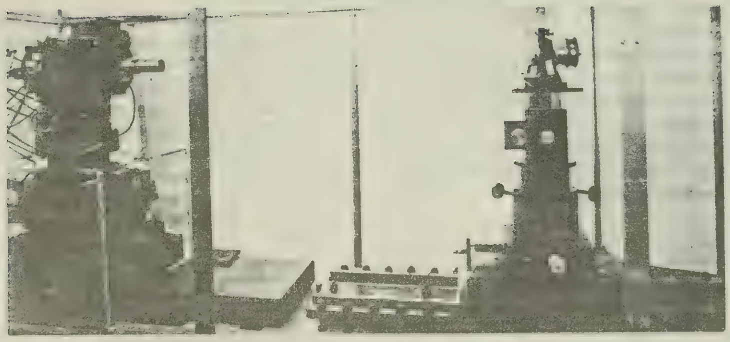


Fig. 8. A precise measuring machine to measure the shape of super mirror for the Photon Factory. The shape of the mirror can be measured within the accuracy of 0.01 μm/100mm.

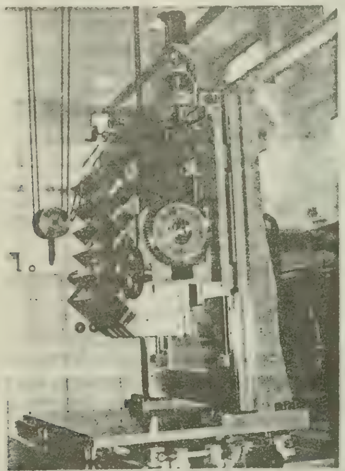
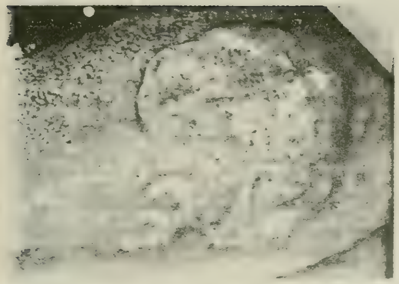


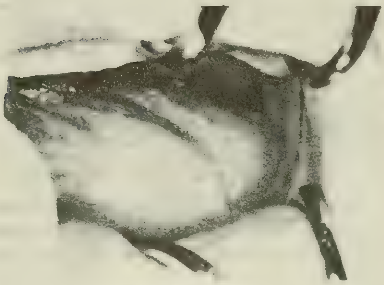
Fig. 9. A calibration instrument for lead glass of VENUS detector.

Booster Synchrotron Utilization Facility

Tongue cancer

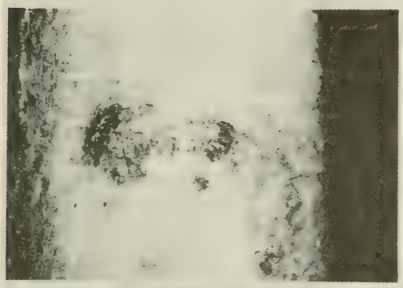


Before treatment

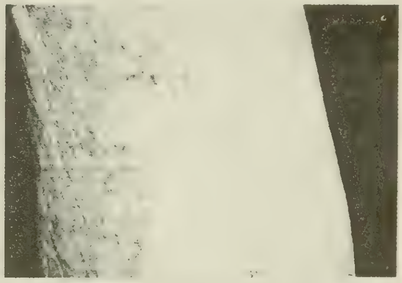


6 months after treatment

Skin cancer



Before treatment



12 months after treatment

Clinical application of proton beam irradiation at the Particle Radiation Medical Science Center

The Booster Synchrotron Utilization Facility has been operating successfully since commissioning in 1980. The scientific research program is well under way in the KENS spallation neutron source facility, as well as in the pulsed muon facility BOOM. The number of the experimental proposals is steadily increasing in these facilities. Due to increasing demands on machine time, several common use instruments have been installed, and some of them are now in operation: High resolution powder diffractometer HRP, Medium resolution powder diffractometer MRP, High resolution quasi-elastic spectrometer LAM-80 in KENS, and a 37 kG superconducting Helmholz coil with a large room-temperature access space in the pulsed muon channel of BOOM.

The recent research activities in the meson science laboratory were summarized at the conference on Muon Spin Rotation and Associated Problems held at Shimoda, from April 18 to 22, gathering 117 participants from 12 countries. The spotlight of attention was focused upon the uniqueness of this world's first pulsed muon facility. Among the many results from neutron scattering experiments, the first neutron scattering experiments at very high Q from superfluid He II, using an eV spectrometer RAT, caused quite a stir due to its evaluation of the fraction of the Bose-condensation, which had seemed to be almost established, both theoretically and experimentally.

One of the highlight activities in BSF for this fiscal year is the commencement of clinical trials for cancer treatment using proton beams in the Particle Radiation Medical Science Center. It is an exciting fact that out of 24 patients treated for a year, 22 cases of various kinds of cancer showed no clinical evidence of recurrence or residual disease after completion of the proton beam irradiation.

Design studies for the intense pulsed neutron and meson source GEMINI are in progress. On the other hand, the advisory committee for the BSF future program has discussed the financial scale of the new project, the construction schedule, etc. The conclusions of the discussion were reported to the committee for the Booster Synchrotron Utilization Facility.

BEAM LINE

Operation

The summary of BSF operation in FY 1983 and the average beam intensity and transmission data in each operation period are shown in Tables 1 and 2 respectively. The beam time used for BSF operation amounts to 2789.1 hours, which corresponds to 76.0 % of the PS operation time, 3666.7 hours. This percentage is 12 % lower compared with that of FY 1982, because the PS operation in September and October was devoted to the accelerator study of H^- injection and polarized beam acceleration. From January 10 to 13, the booster synchrotron was operated for the Particle Radiation Medical Science Center. The beam time for medical use has increased by a factor of 2.4 compared with that of FY 1982. To utilize the booster beam more efficiently, the interlock system was reinforced so that neutron or meson experiments can be done during the time used for preparing patients in the medical treatment room. Regarding Table 2, beam intensity was measured on the 500 MeV beam line nearest to the targets or the energy degrader. Transmission is defined as the ratio of the beam intensity measured this way to the booster intensity displayed on the CATV. The beam intensity integration system was replaced by a new version which consists of CAMAC ADC and timing modules and a micro-computer. This new system was into operation beginning with the first operation cycle in November and shows good stability.

Table 1. Summary of BSF operations since April 1982 through February 1983

(units are "hours", unless otherwise specified.)

	Neutron Experiment	Meson Experiment	Biomedical Research	Total	Ratio
Beam utility					
Beam ON	1117.4	1115.5	417.2	2650.1	95.0 %
Reject	1.0	1.8	0.3	3.1	0.1
Beam line trouble	2.4	10.3	2.1	14.8	0.5
Accelerator trouble	26.5	48.5	12.5	87.5	3.1
Others	2.0	2.1	0	4.1	0.2
Beam line tuning				29.5	1.1 %
Summation	1149.3	1178.2	432.1	2789.1	100.0 %

Table 2. Beam intensity and transmission

	Neutron		Meson		Biomedical Use	
	Average Intensity (10^{11}ppp)	Transmission	Average Intensity (10^{11}ppp)	Transmission	Average Intensity (10^{11}ppp)	Transmission
1983 April – July	4.6	0.91	4.6	0.90	5.3	0.98
1983 November – December	4.6	0.81	4.3	0.78	4.5	0.79
1984 January – February	4.8	0.82	4.9	0.86	4.7	0.84

(Transmission includes the beam extraction efficiency of the booster synchrotron)

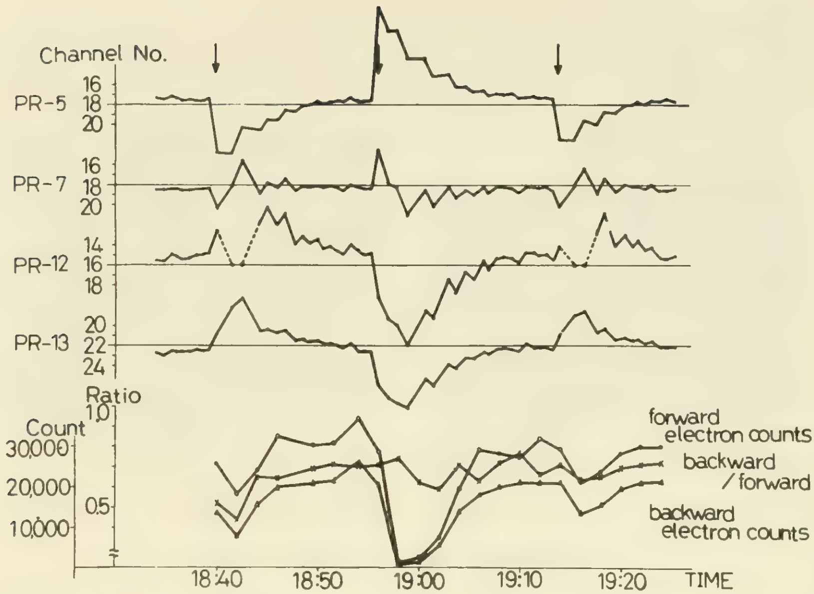
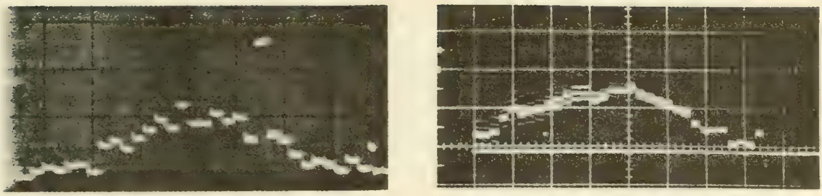


Fig. 1. Test of the auto-beam-steering system. Arrows show the disturbance caused when the bending angle at PHB1 was intentionally changed. Channel divisions are 2.5 mm.

The BSF beam line control room has been extended to help relieve the severe shortage of space where the control equipment is accomodated. Simultaneously, a new access route to the beam dump room was opened. By using this route, it is possible to reach the dump room directly from the BSF control room, without disturbing the PS operation. This will make maintenance of the power supply easy, which is placed beside the dump room.

Instrumentation

Small deviations of the primary proton beam in the horizontal direction gives rise to an enormous decrease in the surface muon production rate and in the secondary proton beam intensity after passing through the small aperture energy degrader. An auto-beam-steering system was installed in the mid-point of the beam line to eliminate such deviations. A pair of horizontal steering magnets is controlled automatically by a micro-computer to restore the beam positions at the corresponding beam profile monitors when the beam center is shifted from the originally-optimized position. Fig. 1 shows the results for a test of this auto-steering system. Beam deviation upstream was simulated by adjusting the bending angle in the PHB1 magnet, which switches the beam pulse from the main ring injection line to the BSF beam line. PR-5 and PR-7 are the profile monitors which correspond to the pair of steering magnets. PR-12 and PR-13 are those nearest to the meson production target. The recovery times for the beam positions and the surface muon production rate are less than ten minutes, as is seen from the figure.



(a) (b)

Fig. 2. Comparison of the beam profile signals.
(a) 30 μm tungsten wire.
(b) a pair of 50 μm tungsten wires. Preamplifier is placed 60 m away from the monitor head.

Preamplifiers which are placed close to the profile monitor heads are easily damaged by the radiation along the beam line and their maintenance is really tedious work. Each mesh of 30 μm tungsten wires on the monitor head was replaced by a pair of 50 μm tungsten wires to increase the S/N ratio and to thus enable placement of the preamplifier far away from a beam line. Fig. 2 shows a comparison of output signals from a mesh composed of single wires and that composed of pairs of tungsten wires. In the latter case, the preamplifier is placed in a cable pit 60 m away from the monitor head. The beam profile can be clearly seen, even though the beam shape is a broad peak. Study to replace the tungsten wires by wider and thinner strips is now in progress.

NEUTRON SCATTERING EXPERIMENTAL FACILITY (KENS)

Outline

The pulsed spallation neutron source KENS at KEK has been successfully operated for three and a half years, and is now shut-down for TRISTAN tunnel construction. The average beam current of 500 MeV protons has been only 1.5 μA at the neutron-generating target and the beam time has been very limited, but many pioneering studies have been successfully completed in the field of condensed matter research with neutron scattering. Figure 3 shows the recent status of the instrumental installation in the experimental area at KENS. Twelve instruments were in operation and open for outside university users, and three are under construction or development. The total number of beam tubes is thirteen, including three cold neutron guiders. therefore, some tubes are used by two instruments; for example, HRP utilizes the beam through LAM-40 (see C4 beam line in Fig.3).

First generation spectrometers HIT, LAM-40, MAX, SAN and TOP have been utilized extensively for many scientific programs. The results are summarized in the activity report (KENS Report-V).

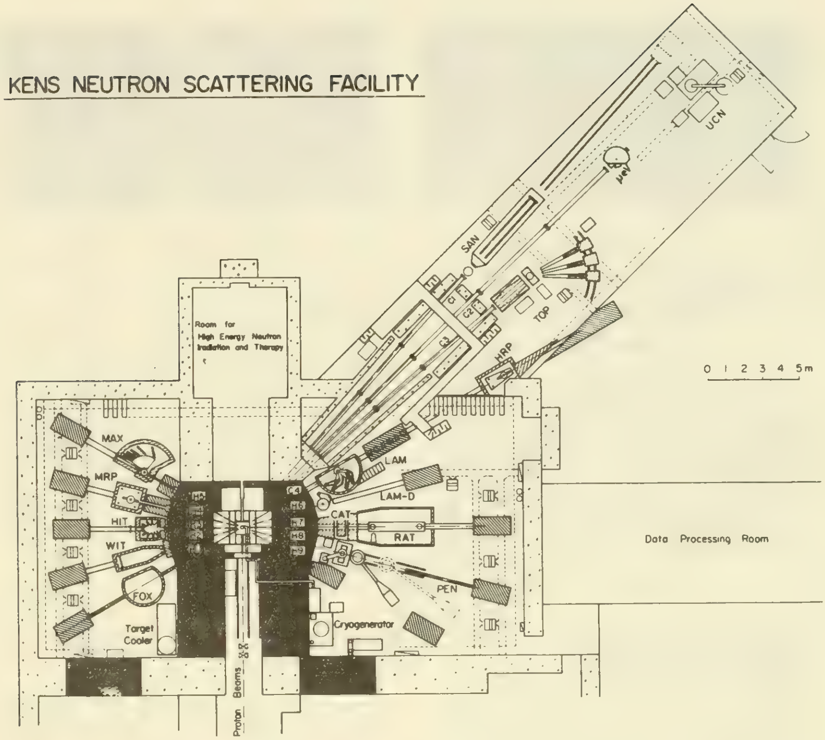


Fig. 3. The recent status of the instrumental installation in the KENS experimental area.
H1 ~ H9 : thermal and epithermal neutron beam holes.
C1 ~ C4 : cold neutron beam hole and guiders.

H1 : Single crystal diffractometer (FOX).
H2 : Thermal neutron small angle instrument (WIT), under construction.
H3 : Liquid and amorphous spectrometer (HIT).
H4 : Medium resolution powder diffractometer (MRP).
H5 : Multi-analyzer crystal spectrometer (MAX).
H6 : Molecular spectrometer (LAM-D).
H7 : eV-spectrometer (RAT). Crystal spectrometer for high energy incoherent scattering (CAT).
H8 : Polarized epithermal neutron spectrometer (PEN).

C1 : Small angle instrument (SAN).
C2 : High resolution quasi-elastic spectrometer (LAM-80). Spin echo μeV spectrometer prototype (μeV), under construction. Ultra cold neutron generator test machine (UCN).
C3 : Polarized cold neutron spectrometer (TOP).
C4 : Medium resolution quasi-elastic spectrometer (LAM-40).

Figure's 4 and 5 show the distribution of the beam time in FY 1983 in various fields and for each spectrometer.

The KENS-I' project, which aims to realize 10 times higher neutron intensity by improving the existing accelerator and the neutron generating target, is now in progress.

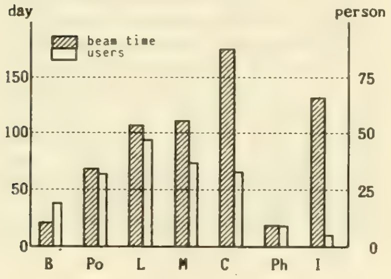


Fig. 4. The distribution of the beam time and number of users in FY 1983 in various fields. B:biology, Po:polymer, L:liquids & disordered solids, M:magnetic structure & excitations, C:crystal structure & lattice dynamics, Ph:phase transitions, and I:instrumentation.

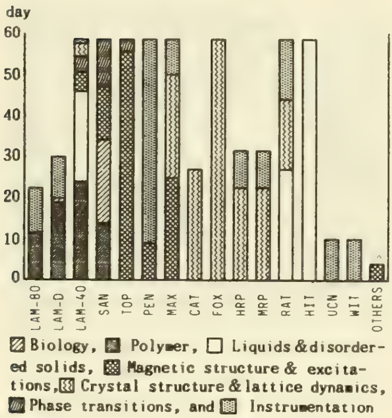


Fig. 5. The distribution of the beam time in various fields.

Status of New Spectrometers

A pulsed spallation neutron source with an eV-spectrometer can enlarge the experimentally-accessible range of momentum transfer, Q, by a factor of more than 10, and it became possible to determine the momentum distribution of scattering particles by means of neutron scattering at very high Q (< 100 A^{-1}). One of the most exciting experiments of this kind is the determination of the fraction of atoms in the quantum-mechanical ground state (Bose-condensate), and a first neutron scattering experiment at very high Q (~ 150 A^{-1}) from superfluid He-II has been performed using the eV spectrometer RAT at KENS, which is based on the resonance detector. The results are shown in Fig. 6. A distinct difference can be seen between the two spectra for He-I and He-II. From the difference, a Bose condensate fraction of about 35 % was determined, which is about three times larger than the reported values determined from measurements at modest Q (< 15 A^{-1}).

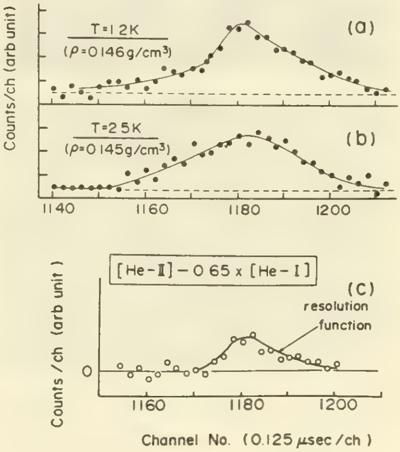


Fig. 6. Bose condensation in superfluid ^{4}He

Construction of the high resolution quasielastic spectrometer, LAM-80, was completed in October 1983. Energy resolution of this instrument is about 10 μeV, with resonably high counting rates. This is a highest resolution achieved by a pulsed neutron source. The instrument is of an inverted-geometry type, which is installed at the end of the extended C2 guide tube, about 30 meters from the 20 K grooved solid methane moderator. Scattered neutrons at a fixed energy are detected by a quasi-spherically curved analyzer mirror consisting of 72 pieces of pyrolitic graphite (LAM type) at quasi-back reflection angle ($\theta_A \sim 80^\circ$). The instrument has four movable analyzer-detector arms which can cover the range of momentum transfer 0.15 $\sim$ 1.7 A^{-1}. Figure 7 shows a photograph of LAM-80 with its schematic diagram.

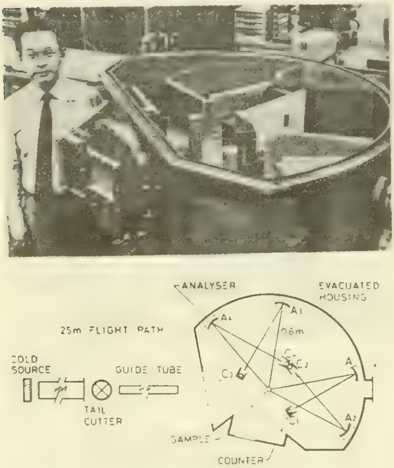


Fig. 7. High resolution quasi-elastic spectrometer (LAM-80).

A μeV spectrometer prototype is under development, intended to realize an energy resolution better than 1 μeV by a modified spin-echo method using pulsed cold neutrons.

Two powder diffractometers, HRP and MRP, have been constructed. HRP is a high resolution instrument and $\Delta d/d \sim 0.2$ % has been attained by utilizing narrow pulses of thermal and epithermal neutrons from the 20 K solid methane moderator incorporated with a 20 m long flight path and backward counters at about $2\theta = 170^\circ$. Figure 8 illustrates part of a measured time-of-flight diffraction pattern from an Al_2O_3 sample at room temperature, with a preliminary Rietveld refinement. MRP is a conventional instrument with medium resolution installed at beam hole H4 which views the room temperature moderator.

Considerable progress has been achieved in a polarized epithermal neutron spectrometer, PEN. The polarizer is a dynamically polarized proton filter (ethylene glycol containing few percent of Cr^{V} complex). Proton polarization of about 85 % was achieved with a bead type filter which was directly cooled by liquid ^3He down to 0.5 K. As a neutron polarizer, a slit-type filter was tested, but the proton polarization was only 65 %. A large size filter of bead type, bathed in liquid ^4He which is cooled to 0.5 K by liquid ^3He, has been constructed for a neutron polarizer. The new filter turned out to realize higher proton polarization, i.e., higher neutron transmission. Figure 9 shows a photograph of the PEN.

The construction of an ultra-cold neutron (UCN) generator prototype (Fig. 10) was completed. A superthermal UCN converter (Mark-280) was cooled down to 0.55 K in February 1984 (KEK Report 84-2). The device was designed to provide data for the planning of a larger converter (Mark-3000).

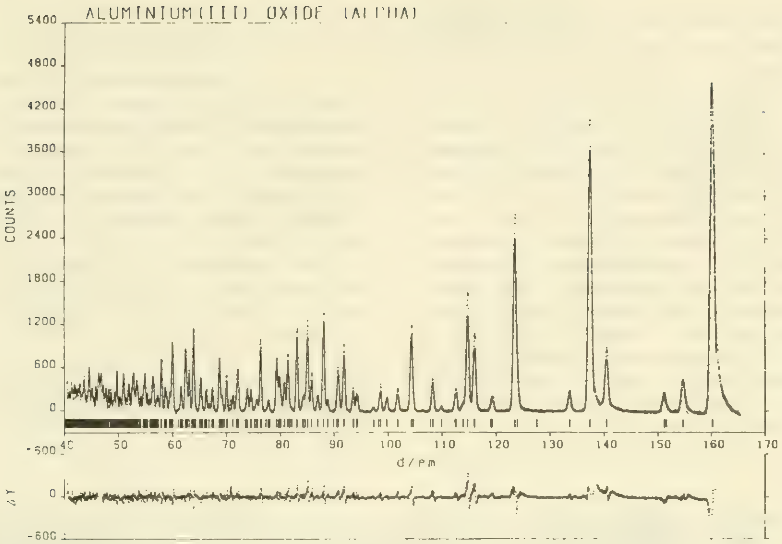


Fig. 8. A part of time-of-flight diffraction pattern from Al_2O_3 powder measured by HRP.

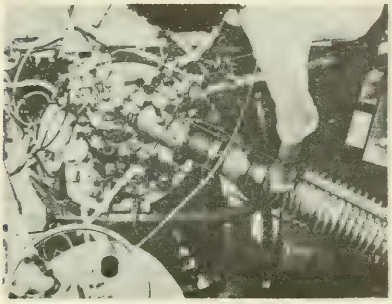


Fig. 9. Polarized epithermal neutron spectrometer (PEN).

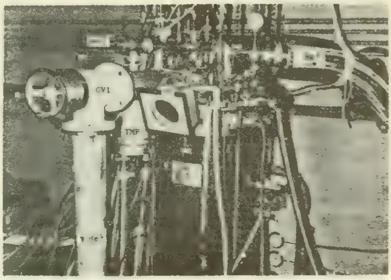


Fig. 10. UCN generator test machine (UCN).

MESON SCIENCE LABORATORY

Introduction

The highlight of early FY 1983 was the organization of the Yamada Conference on Muon Spin Rotation and Associated Problems (μSR 83 for short), which was held at Shimoda from April 18 to 22. The conference was sponsored by the Yamada Science Foundation. The city of Shimoda is the historic site where the first American consulate was established more than a century ago, forming a "bridge" between Japan and the West. This μSR conference, like its predecessores μSR1 (Rorschach, 1978) and μSR2 (Vancouver, 1980), was intended to establish a similar "bridge" between the dissimilar scientific cultures of particle/nuclear physics and materials sciences, like chemistry and condensed matter physics.

In this μSR 83 conference, there were 43 Japanese participants and 74 foreign participants from 12 other countries (see Fig. 11). In total, 134 papers were presented during the conference. The main subjects were (a) local magnetic fields and fluctuations at the interstitial μ^+ in magnetic materials, (b) quantum diffusion and impurity-mediated trapping of μ^+ in metals, (c) muonium formation and behavior in semiconductors and insulators, (d) chemistry of muonium in gas and liquid phases, (e) hyperfine structure of muonic atoms, and (f) electroweak interactions, etc. The conference proceedings have already been published by J.C. Baltzer AG., Basel.

As for the activities at the BOOM (Booster Meson) facility at BSF of KEK, we have enjoyed 1,300 h of BSF beam time during FY 1983. New progress has

Fig. 11 Yamada Conference μSR 83.

been marked in the various condensed matter studies with positive and negative muons.

Facility Development

The major installation which has been carried out in this period is a construction of a large 37 KG Superconducting Helmholz Coil (SHC) at the μ2 port of the superconducting muon channel. The final form of the SHC is shown in Fig. 12. It has a large room-temperature access space to the central field: 24.5 cm longitudinal bore all the way along the field axis plus a transversal gap of 10 cm width and 90 cm height. In order to support the two coils against a huge attractive force, a special yoke-bobin structure was designed. The construction was started in October 1983 The replacement of SLC (Superconducting Longitudinal Coil set-up) with SHC was undertaken in December 1983. The testing of the SHC followed and a nominal field of 37 kG was achieved in January 1984.

There are two important features in the functions of SHC: a) decay $e^{\pm}$ from $\mu^{\pm}$ stopped inside the target, located at the center of SHC, is completely confined inside the open bore of SHC, where an additional access space is available in the transverse gap for the X-ray or neutron detectors; b) an r.f. cavity with beam window can be installed in the transverse gap, providing a capability of 500 MHz $\mu^{\pm}$ spin resonance under a 37 kG longitudinal field.

Several new and important experiments will be made possible by using this SHC set-up. Concerning the above-mentioned feature a), the muonic X-ray from pulsed μ^- stopped in carbon was successfully observed with a Si(Li) detector in a geometry of the decay e^- confinement. The rare photon or neutron events from muonic atoms will be measured. As for the feature b), 16 channel μe decay telescopes were installed in both forward and backward directions to detect decay $e^{\pm}$ in the digital method. The 500 MHz resonance cavity as well as 10 kW pulsed rf sources are in preparation for μ^+ chemical shift measurements.

Several other technical developments have been performed for other parts of the BOOM experiment: a) Muon spin resonance experiments were applied to the target at various temperatures from 4 K to 400 K with the help of a specially designed cryostat and oven; b) on-line data taking methods have been used for the spin resonance and decoupling measurements; c) New counter systems for μe and μSR measurements were developed by using a complex of MWPC's.

The present layout of the experimental hall is shown in Fig. 13. During the long shut-down of the whole BSF facility, expected in the coming FY 1984, the following major modifications will be carried out;

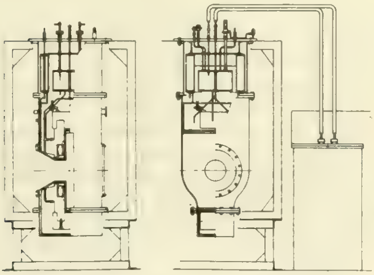


Fig. 12. Superconducting Helmholz Coil set-up (SHC).

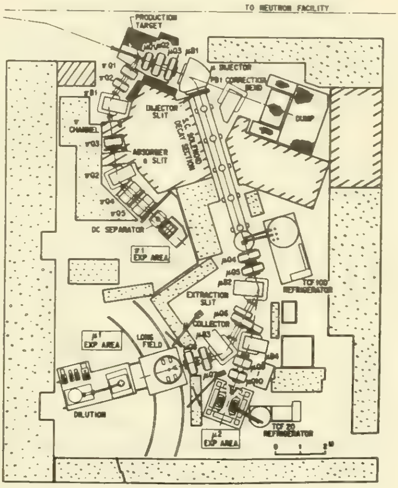


Fig. 13. The layout of experimental hall of the Meson Science Laboratory (March 1984).

a) installation of a new surface μ^- channel at a take-off angle which is further backward from the existing pion channel, b) in order to obtain slow μ^-, the whole beam line of the superconducting muon channel will be connected in common vacuum from the production target to the experimental target, except for two thin foils at the superconducting solenoid, c) with expectations for 10 μA operation after Fall 1985, the heavy concrete radiation shields near to the primary line will be replaced with iron plates.

Experimental Program

The list of experiments which have received beam time during FY 1983 is shown in Table 3. A short description is given here for the achievements of each active experiment.

1. Condensed Matter Studies with Pulsed μ^+ SR

1a) *Zero-field μ^+ SR Studies of μ^+ Quantum Diffusion in Cu at Very Low Temperature (M22)*

The ZF μSR experiments on μ^+ in Cu have been extended to further lower temperature, down to 69 mK. As shown in Fig. 14, the μ^+ hopping takes a temperature dependence of $T^{-0.4}$ in the temperature range from 15 K down to 0.5 K, from where a clear level-off behavior is also seen. These low temperature data are clearly demonstrating a new type of coherent μ^+ diffusion, which was very recently explained by the two theoretical papers by J. Kondo and K. Yamada in the light of basic mechanisms for the muon-electron interactions in metals.

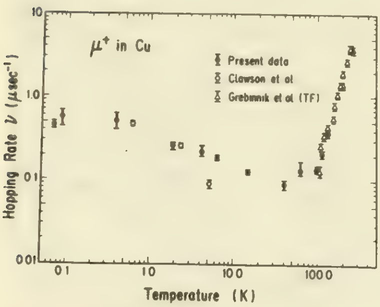


Fig. 14. Extracted hopping rate of the μ^+ in Cu at various temperatures.

1b) *Observation of Fine Structures in ZF-Relaxation Function for μ^- in Cu (M22)*

With high statistics measurements on the longitudinal relaxation function under zero-field for μ^- in Cu at 15 K, we have seen a clear oscillating behavior in the one-third recovery part, as shown in Fig. 15. The behavior was consistently explained by Holzschuh and Mair's theory which emphasizes the importance of the non-Gaussian distribution of the nuclear dipolar fields at the μ^- site.

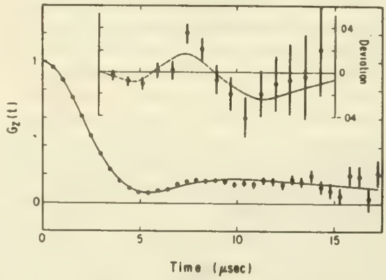


Fig. 15. Observed ZF relaxation function of μ^+ in Cu at 15 K and the fitted curves of Kubo-Toyabe relaxation function (——). The deviation is consistent with Holzschuh and Mair's theory (- —).

1c) *Solitons in Polyacetylene "Induced" and Probed by Positive Muons (M33)*

Positive muons were injected into both trans- and cis- $(CH)_x$ as well as $(CD)_x$. A clear contrast was seen in the longitudinal relaxation function under various longitudinal field H, as demonstrated in Fig. 16. In cis-polyacetylene, the μ^+ was found to form a radical state with an unpaired π-electron localized near the μ^+. In trans-polyacetylene, this induced unpaired π-electron was found to be highly delocalized; the longitudinal μ^+ spin relaxation rate showed $H^{-1/2}$ dependence on the applied field H down to

Table 3. List of active experiments

(April 1983 – March 1984)

EXP. Number	Title ———: New Proposal	Beam Time (h) $\mu1$ (BWD)	$\mu2$ (BWD)	$\mu2$ (FWD)	$\pi1$
M-1	Construction of pulsed muon channel and beam tuning experiments				
	Primary Beam Tuning	11.2			
	Slow μ Test		35		
	SHC Tuning		7		
	$\mu2$ Tuning			166	
	MWPC Tuning			23	
M-2	Construction of pulsed pion channel and beam tuning experiments				
	Surface μ^+, Mu Tuning				320
M-3	Developments of μSR methods using pulsed muons				
	REAL, CMN Test	21.6			
	GaP Test		12		
	Polyacetylene Test		79.2	28	
	CoTi, etc Test			42	
M-7	Knight shift measurements of μ^- in C_8K and $C_{24}K$				
	μ^+ Decoupling C_8K, $C_{24}K$	33.6		139	
M-8	Muonium in hydrocarbons				
	μ^+ and Mu in CS_2, C_6H_6, etc.		129		
M-10	Measurement of average polarization of ^{12}B in μ^- capture reaction on ^{12}C				
	μ^- in ^{12}C contribution Test	21.6			
M-11	Studies of lattice defects and phase transition by positive muons				
	μ^+ in AlMg, amorphous NiSiB				48
M-12	Hyperfine effect in light muonic atoms				
	hf conv. in ^{13}C and ^{14}N		106		
M-16	Negative muon spin repolarization				
	μ^- Bi Tuning	26			
M-20	Spin fluctuation in weak itinerant				
	ZF MnSi, Double Resonance				66
M-22	Quantum diffusion of μ^+ in Cu				
	ZF μ^+ SR in Cu, etc.	57			40
M-24	Studies on pulsed muon and muonium resonance				
	Polyacetylene resonance-hunt		11	98	
M-25	μ^+SR studies on valence fluctuating systems				
	μ^+ in Sm_3Se_4				51
M-26	Chemical analysis by atomic μ^- capture				
	μ^- capture in organic compounds			153	
M-27	μ^+ trapping by extended defects in metals				
	μ^+ in irradiated Al, etc.				119
M-28	Pulsed laser resonance sectroscopy				
	MU + NO_2				38
M-29	μ^+SR studies on magnetism with competing ordering				
	μ^+ in $Fe_xCO_{1-x}TiO_3$				281
M-32	μSR studies of amorphous rare earth magnets				
	μ^+ relaxation in DyAg				139
M-33	Decoupling and resonance studies on polyacetylene and other materials				
	μ^+ in cis-, trans- $(CH)_x$ and $(CD)_x$	218		20	
M-34	Muonium resonance spectroscopy in gases and powder surfaces				
	Diamagnetic-μ^+ in alkali halides	266		12	57

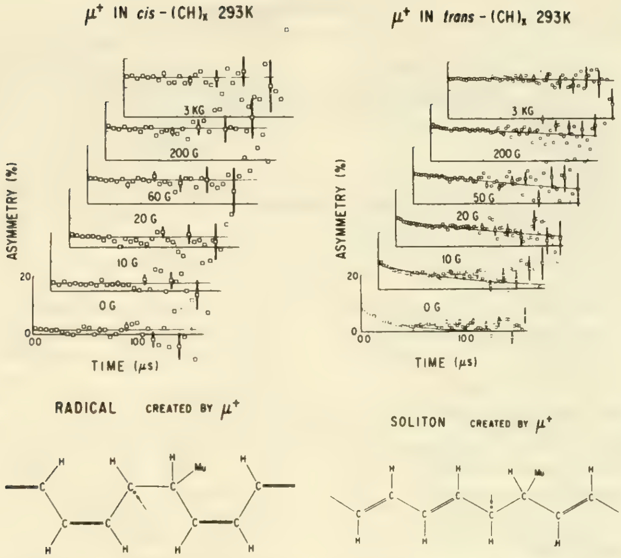


Fig. 16. Relaxation function of μ^+ in cis- and trans- $(CH)_x$ observed at room temperature for various applied longitudinal magnetic field. The proposed pictures for the muonium states in these two isomers are also shown.

10 G (130 kHz) at 293 K. This is quantitatively explained as one-dimensional motion of the muon-induced soliton.

1d) *Muon Spin resonance Probing μ^+ States after Muonium Reaction in Alkali Halides (M34)*

The state of positive muons in typical alkaline halides (NaCl, KCl and KI) were probed by the pulsed muon spin rf resonance method with the pulsed muon beam. Under an 0.3 T decoupling field, which recovers μ^+ spin polarization, a considerable fraction of the injected muons has been found as μ^+ in diamagnetic species, which increases with an activation-type temperature dependence, as shown in Fig. 17. The origin of these fractions, after combining experimental results of asymmetry increase pattern versus longitudinal field, can be attributed to the products of muonium reaction in the solid. The results are revealing important chemical reactions of muo-

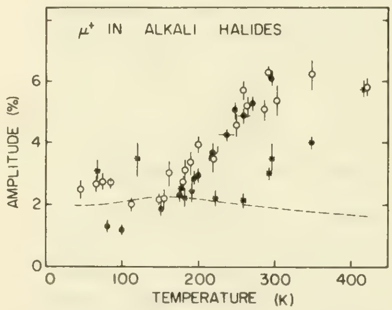


Fig. 17. Temperature dependences of diamagnetic μ^+ fraction in various alkali halides NaCl (●), KCl (o), KI (*) observed by muon spin resonance. The broken line shows the results of transverse field method in KCl.

nium undertaken with the mobile paramagnetic species produced by the injected μ^+ itself.

1e) *μ^+ SR Studies on Spin Dynamics in a Mixed Antiferromagnet with Competing Magnetic Anisotropies $Fe_x\ Co_{1-x}\ TiO_3$ (M29)*

The positive muon spin relaxation method was applied to probe the spin dynamics in the frustrating magnetic systems with competing magnetic anisotropies $Fe_{0.6}Co_{0.4}TiO_3$, with reference to $FeTiO_3$ and $CoTiO_3$. Below T_N, small but significant enhancement was observed in the relaxation rate for $Fe_{0.6}\ Co_{0.4}\ TiO_3$, which is explained by a correlation time τ_c of the frustrating spins in the range of $10^{-4}\ -10^{-6}$ s, consistent with the result (τ_c is longer than 10^{-7} s) observed by Mössbauer studies. In addition, remarkable spin dynamics was observed in both $FeTiO_3$ and $CoTiO_3$ below T_N, which might be explained by the μ^+ spin relaxation due to the influence of the spin wave excitations, etc.

2. Negative Muon Studies

2a) *Anomalous Hyperfine Conversion Phenomena Obserbed in $\mu^-\ ^{13}C$ and $\mu^-\ ^{14}N$ Atoms (M12)*

A pulsed beam of polarized negative muons was stopped in enriched ^{13}C powder at room temperature and in liquid nitrogen (^{14}N) at 77 K. Transverse magnetic fields were used to precess the upper hyperfine state (F^+) of $\mu^-\ ^{13}C$ and $\mu^-\ ^{14}N$. The slow depolarization rates in the muon spin rotation pattern were observed in both cases: 0.026 (12) μs^{-1} for $\mu^-\ ^{13}C$ and 0.092 (33) μs^{-1} for $\mu^-\ ^{14}N$. The results for both $\mu^-\ ^{13}C$ and $\mu^-\ ^{14}N$ do not agree with the predicted hyperfine transition rate from F^+ and F^-, suggesting either an anomalously enhanced hyperfine transition or an anomalously large difference in nuclear muon capture rates between F^+ to F^- states. Probably, molecular excitation in both the graphite network and the liquid N_2 may contribute to enhance the hyperfine transition rates.

MEDICAL RESEARCH IN THE PARTICLE RADIATION MEDICAL SCIENCE CENTER

Investigations at the Particle Radiation Medical Science Center of the University of Tsukuba showed remarkable progress in 1983 with clinical application of proton beams produced by the booster synchrotron in KEK. The clinical study has started after a three year preparation of facilities and techniques, and has yielded many successes. Details of the research activities are described in this report.

Clinical application of proton beam irradiation

Proton beam therapy has started at the Particle Radiation Medical Science Center (PARMS) of the University of the Tsukuba with cooperation from the National Laboratory for High Energy Physics in April, 1983. The energy of the proton beam was adjusted down from 500 MeV to 250 MeV for medical use and the beam was supplied for four hours every day for use by the multifraction daily irradiation method. Cancer lesions in 24 cases were irradiated through a single fixed field using a bolus designed for each individual case. The treatment for 22 cases out of those was performed on schedule.

Clinical results of the cases are as follows:

1. Cancer lesions of the skin in 4 cases responded well to the proton beam irradiation and melted away. There were no clinical evidences of recurrence and no definite tissue damages due to the irradiation 12 months after completion of the treatment (see figures in the cover page of this chapter).
2. Two tongue cancer cases showed disappearance

of the lesions and no evidences of local recurrences were detected on a clinical basis 6 months later (see figures in the cover page of this chapter).

3. Three cases with a tumor lesion in the H & N region also showed remarkable improvement with no clinical signs of residual disease three months after completion of the irradiation.
4. One case with carcinoma of the uterine cervix in a clinical stage IIIb had proton beam irradiation to the primary lesion and Co-60 γ ray treatment to the intrapelvic lymphnode chains. She is doing well, without any evidence of disease six months later. These clinical results and tumor responses on the proton beam irradiation seemed to be similar to the conventional Co-60 γ ray irradiation. Therefore, it was noted that the proton beams could be used in cancer therapy for radical purposes, using clinical experience in conventional radiation therapy.
5. Two cases with hepatoma, one case with retroperitoneal tumor, nine cases of brain tumors, also underwent the treatment in the past series. All of the cases are doing well to date, except one brain case which did not show sufficient improvement of symptoms and was reoperated after the proton beam treatment. They are to be followed on an out patient basis. In view of the clinical successes, the proton beam treatment is to be continued and more cancer cases in wider ranges, especially for cancers in deep-seated organs, including lung, stomach, rectum etc., will be treated as the candidates of this study.

Newly designed beam control and treatment planning system

A newly designed fine degrader has been installed in the vertical proton beam. Proton energy is degraded by passing through an oil bath at the central concavity, with a variable thickness for the beam inlet. The proton beam range in water can be remotely controlled within ± 0.5 mm with this fine degrader, which has not practically affected the shape of the Bragg peak. The moving velocity of the concavity part is quick enough to vary the full range within a few seconds after remote presetting (Fig. 18).

A large uniform field has been formed by the use of a scatterer and ring collimator assembly. The scatterer thickness will be reduced to meet the dose rate requirement for the case of smaller field irradiation. A semiempirical study was needed to determine the optimum geometry and position for setting this assembly.

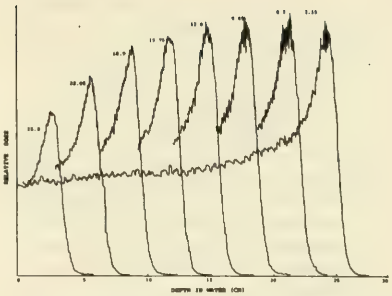


Fig. 18. Depth dose distribution for the proton beam of 250 MeV initial energy and for those degraded by the oil bath with 3 cm steps of oil thickness; density of oil being 1.05.

A treatment planning system based on X-ray CT has been developed with the aid of a VAX 11/750 computer with a graphic display. CT images are obtained with a CE-CT scanner at the Tsukuba University Hospital and transfered to PARMS by magnetic tape. The treatment planning for 10 slices can be achieved in about 2 hours, including data outputs for the bolus fabrication.

Proton Beam Line

In the 1983 fiscal year, the proton beam line was operated for a total of 416 hours in full beam mode and 772 hours in the parasitic mode. About 90 percent of the full beam time was dedicated for proton radiotherapy and others for biological experiments and R and D for the proton CT. The total down time due to the trouble in the beam line was less than a few hours and the beam line operated very well. In order to use the booster beam efficiently, beam sharing with the meson or neutron facility was introduced at the time of proton radiotherapy. Data from the SEC profile monitors can be read into a computer through a CAMAC interface. Interlock release boxes for the shield doors were installed at the front of the two pro-

ton irradiation rooms, to make it possible for the medical doctor to enter into the radiotherapy room as soon as possible at the time of an emergency with the patient. Safety is guaranteed by stopping the beam and by switching off the first beam line magnet when the interlock release button is pushed.

Proton Computed Tomography

Equipments for proton computed tomography were constructed and installed in the horizontal irradiation room (see Fig. 19). The equipment includes a mechanical chopper with rotating chair, three spectrometer magnets with vacuum chambers and the position detector at the image plane of the spectrometer. The mechanical chopper is a beam scanning device to generate and scan about twenty pencil beams collimated from the broad and parallel beam and to cut the scattered beam in the object. It consists of two sets of pairs of slits, one of which defines the sliced beam and the other produces the multi-pencil beam from the sliced beam. These slits are driven by a servo system, using high-pressure oil, to scan the multi-pencil beam. The precision of the position was found to be less than 50 microns, which met our requirement.

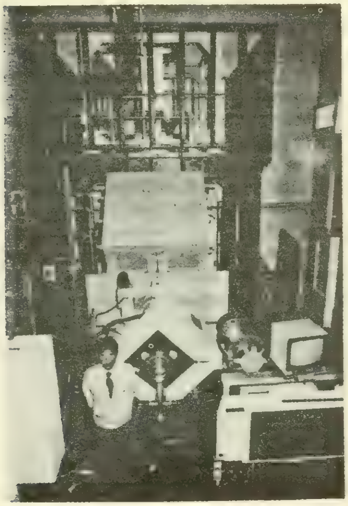


Fig. 19. Equipment for the proton CT.

The magnetic spectrometer is of the QDQ double-image type and was tuned with the proton beam. First we determined the absolute value of the average energy of the proton beam with a dE/dx counter plus an aluminum degrader of variable thickness. Using the beam, the beam optics of the spectrometer was tuned with an image detector (X-ray film) near the focus point of the spectrometer. The spectrometer was found to resolve at least dp/p = 0.12 %, which corresponded to the integrated CT number of 3. A schematic diagram of a unit of the detector for the center of gravity of the multi-pencil beam is shown in Fig. 20. It is an array of plastic scintillator of size (430 mm × 10 mm × 2 mm) combined with a filter on the top, the transmission ratio of which varies linearly with coordinate in the direction of momentum dispersion. Two photomutipliers viewed the scintillator from either side, to monitor the intensity of the beam pulse. Another photomultiplier viewed through a light fiber the scintillation light transmitted through the linear filter placed at the top of the scintillator. The filter output (V), divided by the sum of the beam intensity monitors (A + B) was considered as a signal indicating the center of gravity of the beam. The performance of the detector was examined with beam and was found to have some difficulties in normalization and in precision.

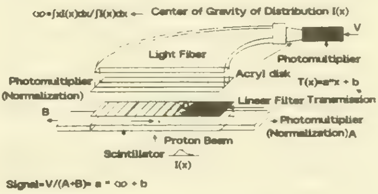


Fig. 20. Schematic diagram of a unit of the position detector.

The signal from the position detector was converted using ADC's and read into the memory of a microcomputer, Microhandler. The Microhandler has a 16-channel digital I/O port, 32-channel 12 bit analog-to-digital converter, and a pulse motor controller.

It controls all of the CT device, takes CT data, and sends the data to a host computer, VAX-11/750 by commands sent from a host computer through RS-232C. We developed a data acqusition program for the proton CT. The program resides in two parts: the one resides in the host computer, the other in the microcomputer. The host computer is always master and the microcomputer is always the slave. The digital I/O port was used to monitor the status of the mechanical chopper, beam ON/OFF and the moving table of the detector and to control the mechanical chopper and the beam interlock etc. We prepared a set of commands in the Microhandler so that control of the Microhandler can be made from the host computer. By sending these command strings from the master to the slave, we control all the devices related to the proton CT and take data. This program was found to work well in a test run.

A data analysis and display program was developed to extract the integrated electron density along the beam path from the raw data, to reconstruct the image from the collection of the projection data and to display the reconstructed image on the image display. The operator interactively sets the window level and width with a trackball.

As a whole, all the element of the proton CT, except the detector of the center of gravity of the beam, were found to work well. We will concentrate our efforts on improving the performance of the position detector.

FUTURE PROGRAM OF BSF

Design studies on a proton synchrotron GEMINI for use as an intense pulsed neutron and meson source is in progress. In addition to a more detailed design of each accelerator component, R & D for some technical problems is under way:

1) Production of prototype permanent quadrupole magnets for the drift tube of the injector linac.
2) Design of a chopper for the preinjector beam for minimizing the injection beam loss in the synchrotron.
3) Model tests on the dual resonant-frequency mode operation of the synchrotron magnet for reducing the RF accelerating voltage.
4) Development of a stranded cable with a water-cooling pipe for a rapid-cycling synchrotron magnet coil.
5) Construction of a model of the power amplifier system for the RF acceleration, etc.

And also, experiments such as the test of beam bunch shortening, which is very important to the pulsed μSR experiments, were carried out by practical use of the existing accelerator and experimental facilities.

On the other hand, the advisory committee for the BSF future program has discussed the financial scale of the new project, the layout of the facility, the location of the facility in the KEK site, the construction time schedule, the possible future extension of the accelerator GEMINI, etc. The conclusions of the discussion were reported to the committee for Booster Synchrotron Utilization Facility after being presented and discussed at the third meeting of the BSF future program held on March 1984.

Fig. 21 shows the proposed layout of the new facility.

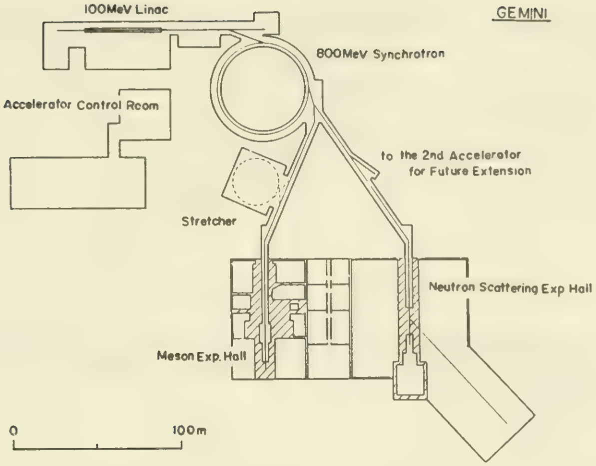
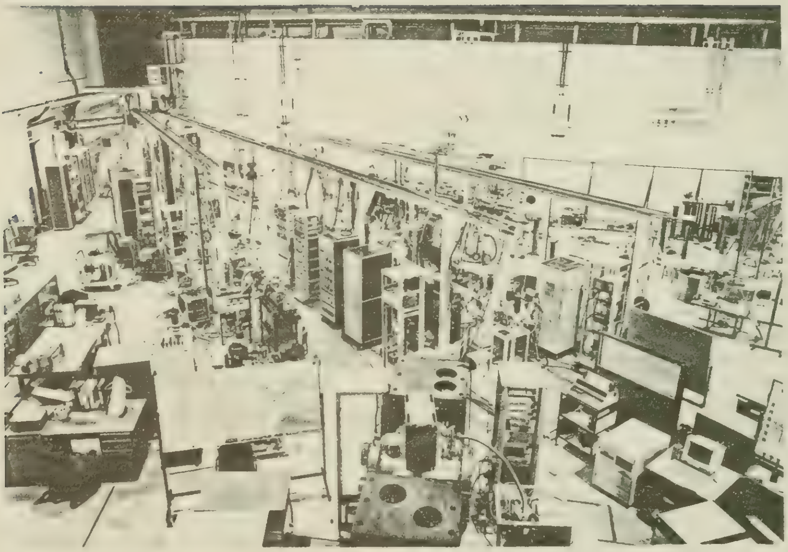


Fig. 21. Proposed layout of a new intense pulsed neutron and meson source.

Photon Factory



A view of the newly constructed beam lines BL 1 and 2 in the Photon Factory experimental hall

The Photon Factory ran steadily throughout FY 1983 and provided abundant photons, from ultraviolet through hard X-rays, for users from universities, research laboratories and industries. They enjoyed stable operation of the light source for most of the beam-time, and a lot of excitement in scientific achievement was experienced, thus making people more and more convinced that the capabilities of synchrotron radiation research are really remarkable.

The entire facility has been opened to qualified users since the beginning of FY 1983, and by the end March 84, 103 proposals have been accepted for use of beam-time. Beam-time assigned to private industries was 686 station-hours for 21 proposals, which corresponds to 3% of the totally available time.

The linear accelerator, serving as the injector of the Photon Factory light source, ran perfectly, without any interruption or any appreciable beam losses, at 2.5 GeV, 50 mA, with one pulse per second.

The linac has also been supplying electron beams to the newly completed 6 GeV Accumulator Ring of TRISTAN since October 83, and a positron injector for TRISTAN is under construction.

The storage ring, the 2.5 GeV light source, ran 2047 hours, or 157 ampere-hours in FY 83, of which about two thirds was made open to users. The rest of the time was spent for tune-up of the machine and for accelerator studies. During that period we have been able to overcome quite a number of different types of instabilities, and as a consequence we achieved a great improvement both in lifetime and in the position stability of the beam. Nevertheless, the storage ring is not yet completely free from instabilities, so that continued efforts in this respect are required.

The most significant developments in this fiscal year were the successful commissioning of the superconducting vertical wiggler and of a 120-pole permanent magnet undulator. Preliminary but exciting experiments on angiography of living specimens and topography of GaAs crystals were performed at the wiggler line (BL-14), and angle-resolved inner-shell photoionization studies of atoms and molecules, and determination of the electron neutrino mass were undertaken using soft X-rays from the undulator. All these experiments demonstrated fantastic extension in the technical feasibility associated with these insertion devices.

Scientific achievements obtained since the first beam-time in June 1982 were summarized in our first publication, the Photon Factory Activity Report 82/83, published in March 1984 and the first annual users' meeting was held in November 1983. Photon Factory News, a regular communication journal intended for prompt correspondence between the inhouse staff and users is being published since June 83.

Developments in collaboration between the Photon Factory and private industry research institutions have been a significant feature in FY 83. NTT (Nippon Telegram and Telephone Public Corporation) beam line (BL-1) has been completed so that studies on soft X-ray lithography and associated research activities were started. Four other collaborational research programs have also been contracted between KEK and five companies.

INJECTOR LINAC DEPARTMENT

Operation of the 2.5 GeV injector electron linac has continued without any serious trouble during FY 1983. Injection of the 2.5 GeV electron beam into the TRISTAN Accumulation Ring was started in October 1983. Total operation time of the linac during FY 1983 was over 2,100 hours.

The PF ring has been operated in a multi-bunch mode since its initial operation. Consequently, for the PF ring injection the beam pulse is wide in the microsecond range. However in the TRISTAN Accumulation Ring single-bunch mode operation is normal. For injection it requires a very short ($<$ 2 ns) beam synchronized with the ring rf. Also the short pulse beam is occasionally required for testing the single bunch mode operation of the PF ring. To provide long and/or short pulse beams for both rings a special injection system was developed.

Since PF injection requires only several minutes and lifetime of the stored beam has been increased to more than 10 hours, PF injection is normally done every 8 hours. During the remaining time between PF injections, the linac beam is used for the TRISTAN Accumulation Ring.

Although the routine operation of the PF ring is multi-bunch mode, if the stored beam fills up all of the rf buckets (312 buckets) it can cause an instability due to ion-trapping. To reduce the instability, a partial-fill-mode (filling 2/3 of the buckets) operation is often effective. For such an operation, synchronized injection is also important.

The linac beam is stable. However, the beam is interrupted for a few minutes whenever a fault in the high power klystrons takes place. As a result of advancements and improvements in the klystrons, the fault rate was reduced to about 30 % compared with FY 1982.

The tunnel and klystron gallery for the positron generator were completed by the end of FY 1982. Six klystron modulators, a gun modulator, about half of the accelerator guides and other components were procured, and their installation and assembling are started at the beginning of FY 1984.

PF Linac Developments

1. Accelerator guides

All of the 40 acceleration units have been operated without any serious trouble during FY 1983. The total operation time of ion pumps exceeds 25,000 hours. Recently, the evacuation ability of the small ion pumps (50 ℓ/s) becomes poor gradually.

A trial fabrication of 4 m long accelerator guide was performed. The guide was made by joining two 2 m long electroplated accelerator guides in series. This long guide was installed into the acceleration unit 5 - 7 (the 7th of sector 5) of the linac, and the test has been continued since October 1983. The result of the test is satisfactory.

Improvement was made in the structure of SiC dummy loads so as to cool the SiC by pure water directly (shown in Fig. 1). Four sets of the improved dummy loads were mounted in the acceleration unit 5 - 6 and were tested. Up to the present, no trouble has been found.

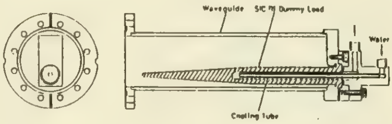


Fig. 1. Improved dummy load. The SiC rf absorber is cooled directly by pure water.

In January 1984, a beam slit was installed into an energy analyzer system located in the beam switch yard to improve the resolution of analyzer. This new system enabled accurate measurements of characteristics of the accelerated beam, such as relation between energy and pulse duration (Fig. 2).

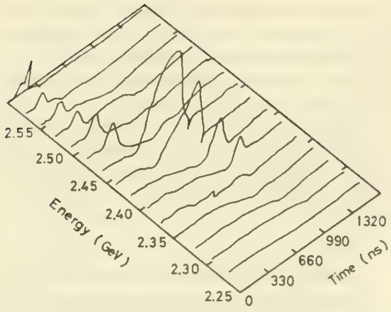


Fig. 2. Time variation of beam energy spectra within a pulse.

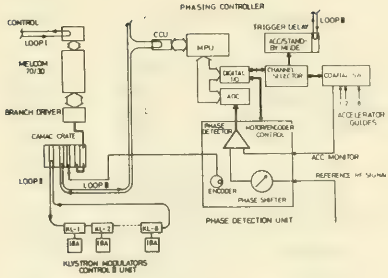


Fig. 3. Block diagram of the rf phasing system.

2. Microwave source

In FY 1983 the rf system on the whole has been run stably with the total operation time of 2,500 h (including high power processing of main klystrons and accelerator guides).

The rf drive system has operated satisfactorily except a few troubles. A main-booster klystron and a sub-booster klystron were replaced because of failure for the former and instability for the latter. Five rf phasing units which adjust the klystron rf phases to the beam bunchs have been developed. Figure 3 shows its block diagram.

The major problem of the rf system is the high power klystron failure. In FY 1983, 11 klystrons were replaced by new ones. Main cause of these failures are due to internal arcing in the electron gun region. Intense improvements of the klystrons have been done and mean ages of the klystrons are increasing recently. Table 1 shows the mean age and MTBF (Mean Time between Failures) of the klystrons during FY 1983 and the cumulative.

The average fault rate of the modulators due to klystron arcing was decreased to about 1.37 times /day/klystron, which corresponds to one time /0.43 h for the 41 klystrons.

3. Control

In May 1983 an rf synchronizing trigger system was built for partially filled multi-bunch mode operation of the Photon Factory (PF) storage ring and for single bunch operation of the TRISTAN Accumulation Ring (AR). A master trigger pulse generated by dividing a 476 MHz signal from a master oscillator is synchronized with the accelerating frequency of the PF ring (500 MHz) or that of AR (508 MHz), and is transmitted to a gun trigger system and five sub-trigger delay units for klystron pulse modulators. The sys-

Table[*] 1. Klystron running data

Per period				Cumulative						
Period	Failured		MTBF	Period		Failured		Living		MTBF
	No of tubes	Mean age (hours)	(hours)		No. of tubes	No of tubes	Mean age (hours)	No. of tubes	Mean age (hours)	(hours)
FY 1983	9	3,500	9,600	up to 1983/3	53	11	1,300	42	2,900	12,500
				up to 1984/4	63	20	2,300	43	4,200	11,200

(*) This table does not include the unused tubes

tem block diagram is shown in Fig. 4.

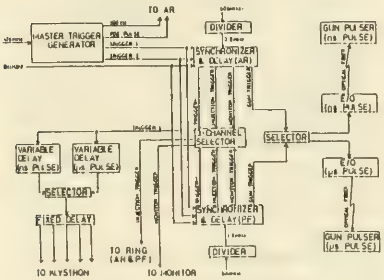


Fig. 4. Block diagram of the trigger system. A trigger pulse is synchronized with the acceleration frequency 500 MHz for the PF ring or 508 MHz for the AR.

Prior to the start of injection into the AR in October 1983, a beam interlock and switching system was installed for unified handling of the safety interlock and beam request signals from the PF ring and AR. Figure 5 shows a display panel for this system.

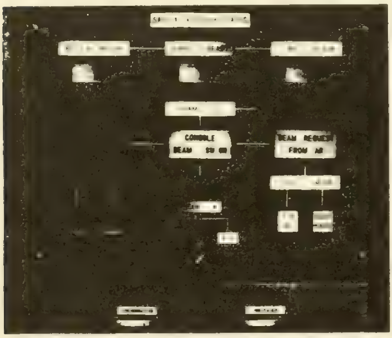


Fig. 5. Display panel of the beam interlock and switching system.

At the beginning of FY 1983, two sets of low-cost personal computers were introduced into the main operator's console to display detailed status of klystron modulators and beam transport system. A klystron status picture can be changed into other pictures by a transparent touch panel mounted on a 20″ color CRT. A light-pen is temporarily used for status display of the beam transport system.

At the end of FY 1983, the display panel for the safety interlock system in the main control room was replaced with a new one which was designed to cover both the PF injector linac and the positron generator under construction.

4. Injector

A short pulse grid pulser for the electron gun and its trigger pulse transmission unit using optical fiber cable have been developed to satisfy the requirement for single bunch operation for both of the TRISTAN Accumulation Ring and the PF ring. The electron gun generates electron beam pulses of about two hundred milliamperes with a duration of 1.5 nanoseconds (Fig. 6). A time jitter less than 30 picoseconds was obtained with the optical trigger pulse transmission unit which consists of a photo-transmitter module, a receiver module and a 30 m long optical fiber cable.

To provide long and/or short pulse beams for both of the PF ring and the Accumulation Ring, an easy and smooth switchover of the beam pulse width is required. The microsecond grid pulser which has been used so far, and the new nanosecond grid pulser are connected to the gun grid in parallel. Therefore µ-sec and n-sec pulses can easily be selected remotely by switching the trigger signal.

Since the high voltage gun pulse modulator used so far was just one modified temporarily from an ordinary klystron modulator, a new modulator for the gun was constructed and tested at full voltage with the gun load during this FY.

Beam Characteristics Investigation and Improvement

Electron beam used for the AR injection has a pulse width of 1.5 nsec with a peak current of 100 to 150 mA, whereas that for the PF ring has a width of several hundred nsec with a current of 30 to 40 mA. The beam energy spread is strongly dependent on the buncher and prebuncher rf phases, so that this dependence was studied to find out optimum phase values for both rings. As a result, the parameter of the

linac to be adjusted is the last high power klystron rf phase only, which corrects the energy difference between both beams arising inevitably from the difference in pulse duration. It takes only a few minutes to tune the linac and to switch over trigger signals to the gun pulsers (described before).

A current monitor for a short pulse beam has been developed. This is of a wall-current detection type, in which a cylindrical solid resister is surrounded by an annular ferite core and covered by a metal shield. It has a fast response with an excellent S/N ratio. Figure 6 shows current wave form with this monitor.

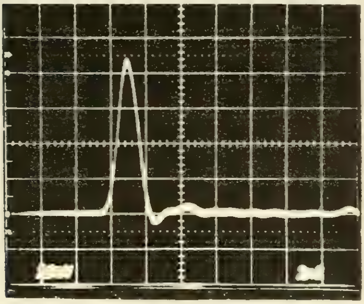


Fig. 6. Typical short pulse beam at the end of the linac.

Another improvement made in beam handling is an installation of a beam delay circuit in the trigger system, it is variable up to 350 nsec in 50 nsec steps, and enables fine tailoring the shape of partially filled bunches by varying the delay during the beam injection into the PF ring.

Beam characteristics were investigated under various conditions. Energy spread was measured at the end of the injection system at various beam currents. The result is shown in Fig. 7. The peak energy decreases linearly with the increase of injection current and the energy spread for low current of less than 100 mA is about 2%. However, for high current the spread increases up to 3 ~ 4%. The bunch width for various injection currents was measured with the result of 1 ~ 2° for low currents and 3 ~ 4° for high currents. This suggests that a space charge effect becomes significant above a beam current of hundreds mA.

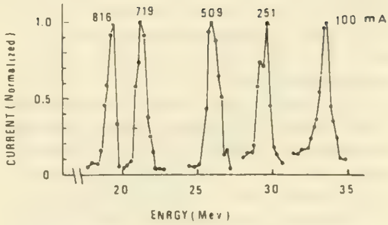


Fig. 7. Energy spectra for various injection currents in the injection system.

In general, an energy spectrum of the electron linac beam is spread due to electrons accelerated in the transient state which have higher energies than the electrons in the stationary state. Therefore, if suppression of energy is made for these higher energy electrons, it can serve to improve the energy spread. This suppression is made by accelerating those electrons with the rising part of rf pulse. An example is shown in Fig. 8; it has much narrower spread than that shown in Fig. 2.

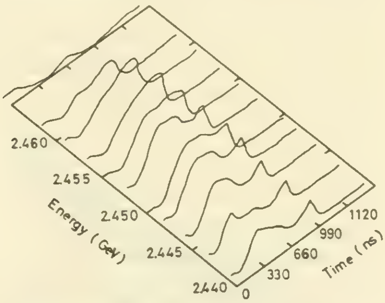


Fig. 8. Time variation of energy spectra within the energy compensated beam pulse.

Concerning high current acceleration characteristics the beam blow up experiment has been continued. Three groups of the blow-up mode frequencies were found: 3.80 ~ 3.90 GHz, 4.20 ~ 4.25 GHz, and 4.33 ~ 4.38 GHz. The latter two are theoretically expected

but the former is not, and the reason is not clear at present.

Positron Generator Construction

1. Accelerator guide

The accelerator guide system for the positron generator consists of 6 acceleration units, each of which is composed of 2 accelerator guides, rectangular waveguides with a hybrid power divider, 3 dummy loads, vacuum manifolds and supporting stands.

The units 2, 3 and 6 have all the same structure as shown in Fig. 9. The unit 1 is an injector unit, consisting of a prebuncher, a buncher, a 2 m guide and a 4 m guide. The unit 4 is the first unit for positron acceleration, consisting of a 4 m guide surrounded by strong solenoid coils, and two 2 m guides connected in series by a waveguide. The unit 5 consists of two 2 m guides similar to unit 4, and a 4 m guide. The units 2, 3 and 6 and the unit 5 were fabricated in this fiscal year.

Beam focusing system was designed on the basis of the beam envelope calculation. All of the quadrupole magnets and their power supplies were fabricated. These power supplies were already installed into the racks located in the klystron gallery.

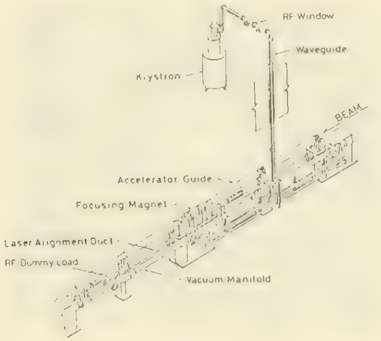


Fig. 9. Structure of the acceleration units 2, 3 and 6.

2. Microwave source

In FY 1983, the greater parts of rf equipments were fabricated. Six main modulators were installed and tested with a dummy load in the klystron gallery for the positron generator (Fig. 10).

Four high power klystrons, 8 pulse transformer assemblies and tanks were also delivered.

Fig. 10. Main modulators installed in the Klystron Gallery.

3. Control

By the end of FY 1983, most of the control system hardware had been provided. The positron generator has its own operator's station to be operable independently of the PF linac; this operator's station is one subcontrol system of the PF linac. The controller for this station is a multi-CPU controlled CAMAC system which consists of 8 bit (6800 type) and 16 bit (68000 type) single board computers and auxiliary crate controllers as shown in Fig. 11. Five sets of personal computers were purchased to be used as graphic displays built into the control panel.

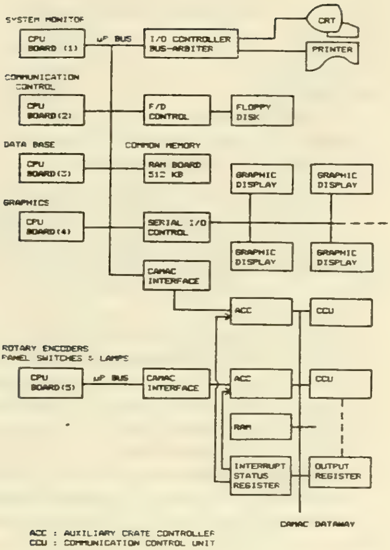


Fig. 11. Block diagram of the subcontrol system.

4. Injector

Basically, the injection system for the positron generator is almost the same as that of the 2.5 GeV linac. However, since a much higher electron beam current was required, the injection system was newly designed. To accelerate sufficient beam current, a high injection voltage more than 150 kV and a high current more than a few amperes are required. A 150 kV pulse modulator and a high voltage station with a grid pulser were procured and installed. In addition, a special bunching system is also required for such a high beam current; consequently, a new injection system including a sub-harmonic buncher, a prebuncher and a buncher was designed, and the beam tracing was completed.

LIGHT SOURCE DEPARTMENT

Storage Ring Operations

In FY 1983 the Storage Ring was operated for 23 weeks; 6 weeks in May to July 1983, 9 weeks in October to December 1983 and 8 weeks in January to March 1984. In a normal operation week the Storage Ring starts at 9 o'clock on Tuesday and ends at 9 o'clock on Saturday. During 96 hours operation, 64 hours are dedicated to user's experiments, 24 hours are used for accelerator study and 8 hours for machine tuning-up.

The total operating time has increased year by year, as Table 2 shows, and the user's time has become beyond two thirds of the total operating time in FY 1983. It is a remarkable thing that, while the user's time was just twice of that in FY 1982, the integrated stored current in the user's run which is equivalent to available photons for users was 2.7 times larger than that in FY 1982. This mainly attributes to improvement in the beam lifetime and, as a matter of fact, the beam lifetime has become longer and longer as the vacuum pressure has been improved through this year.

Table 2. Operation statistics

Fiscal year	1981	1982	1983
Scheduled beam time (hrs)	271	1298	2047
Allotted user time (hrs)		661	1357
Stored current integration (A·hr)		57.7	157.0

As illustrated in Fig. 12, the average stored current has grown up in FY 1983, although the initial stored current was still limited to 150 mA because of a thermal reason. At the end of FY 1983, the lifetime of the stored beam was 10 hours at 150 mA and 20 hours at 80 mA. Consequently, time interval between injections became longer, and at the end of FY 1983 the injection took place once every eight hours.

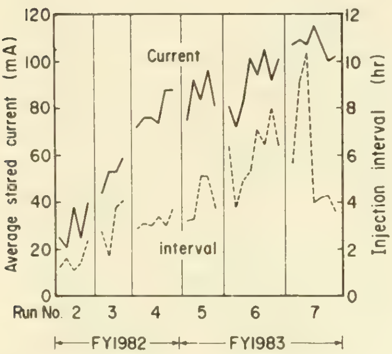


Fig. 12. Weekly average of stored current and injection interval during user's time.

Table 3 summarizes the statistics of user's time in FY 1983. It can be seen that the rate of loss time was very small and the Storage Ring has operated quite efficiently.

Highlights of the Storage Ring in FY 1983 were a success in single bunch operation and a scheduled operation of the superconducting vertical wiggler in the normal user's time. Single bunch injection was succeeded in December 22, 1983. Although single bunch

Table 3. Statistics of user time in FY 1983

Actual user time (hrs)	1241 (91.5 %)
Injection time (hrs)	66 (4.8 %)
Machine failure (hrs)	31 (2.3 %)
Miscellaneous (hrs)	19 (1.4 %)
Number of injection	261
Stored current integration (A·hr)	122.8

operation with more than 20 mA were not practical because of vacuum problem, no instability has been encountered except for the head-tail effect, which could be cured by chromaticity correction. The beam lifetime was about 200 minutes at 20 mA, which was clearly limited by increased vacuum pressure.

From October 1983 extensive study has been carried out to find the best operating condition for the Storage Ring with the wiggler magnet. The scheduled operation began in February 1984 and the user's time of 115 hours was spent in cooperation of the wiggler magnet by the end of March 1984.

Unfortunately, the very last week in FY 1983 operation schedule was lost, because the Storage Ring was contaminated by air which came from the experimental beam line BL-1. Therefore, the storage ring had to be baked again.

Storage Ring Developments

1. Superconducting vertical wiggler

After the first operation of the superconducting vertical wiggler with electron beams in February 1983, helium leak occurred at the welded part of coil case in the cryostat in May, so the wiggler was taken away from the storage ring and moved to the manufacturer for repair. It was reinstalled in the storage ring during the summer shutdown. From November the operation of the wiggler started again with electron beams. The main purpose of the operation in November and December was tuning-up of the wiggler itself, such as to decide the wiggler excitation pattern without closed orbit distortion, and to find the best operating tunes with respect to the beam lifetime. At the same time, experimental beam lines were tuned up using the wiggler radiation. Since February 1984, the wiggler has

been operated in the user's time in parallel with other beam lines.

The power supplies of the wiggler are composed of a main power supply and two auxiliary power supplies connected to two outer coils. The closed orbit during excitation is corrected by applying appropriate correction currents on two outer coils, so as to keep the position of electron orbit unchanged, which is observed by the beam profile monitor. The reproducibility of the beam position was confirmed by observations at several experimental stations and has been turned out to be satisfactory.

Since the betatron frequencies change with the exciting current of the wiggler, they are corrected automatically, by the aid of a control computer, by changing currents of ring quadrupoles QF and QD. It has been turned out that the beam lifetime as well as beam loss during excitation is sensitive to choice of operating tunes, so that reproducibility of operating tunes is important in the operation of the wiggler. This is because higher order resonances become stronger with excitation and a stable region becomes small. As a result of suitable correction, the beam lifetime became satisfactory as shown in Fig. 13.

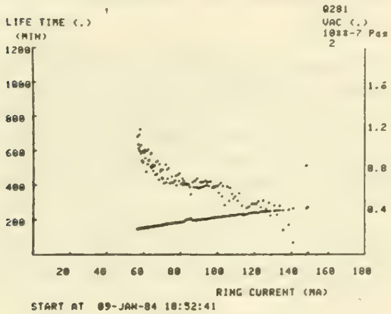


Fig. 13. Beam lifetime and ring average pressure during the wiggler operation.

Liquid helium were supplied by the central cryogenic facility of the low temperature group. Helium were transferred every four hours to the wiggler cryostat through a 12 meters long transfer line from a container which was placed in the service area of the storage ring building. Consumption of liquid helium is 4 liters per hour, and transfer loss is about 50 % of it.

2. Single bunch operation

Single bunch operation is strongly expected by users who are interested in the experiments such as the molecular or the nuclear fluorescence experiments. In the machine physics, the operation in the single bunch mode is suited to study the properties of the ring impedance.

The Linac produces a short pulse of electron beams with duration of 1.8 ns. This pulse is precisely synchronized to the storage ring revolution frequency which is produced from the RF acceleration frequency divided by the harmonic number.

In the single bunch operation, injection took place every second and charging rate was typically 0.03 mA/sec. The maximum stored current was 20 mA, which was limited by vacuum problem. This is because induced fields inside gate valves agitated sealing material (viton) and extraordinary outgassing took place. The vacuum pressure got worse to untolerable value at the location of the gate valves above the beam current of 20 mA.

Figure 14 shows a single bunch signal obtained from a pick-up electrode for beam position monitoring. We have observed the head-tail instability caused by the broad band impedance of the vacuum chamber, and the stored current was limited to 1 mA, when the chromaticity was not corrected. The chromaticity is the quantity representing the fractional dependence of the betatron frequency on the beam energy, which is defined by $\xi = \Delta\nu/(\Delta E/E)$. The natural chromaticity of the ring is -5.4 and -5.0 in the horizontal and the vertical planes, respectively.

Chromaticities can be corrected with sextupole magnets. It has been recognized that the head-tail instability can be cured by correcting chromaticities to zero or slightly positive values. We have measured that threshold current of the instability as a function of chromaticity. As seen in Fig. 15, the threshold of the vertical case is approximately three times lower than the horizontal one. This can be interpreted by the difference of the horizontal and vertical impedances arising from the cross sectional shape of the vacuum chamber.

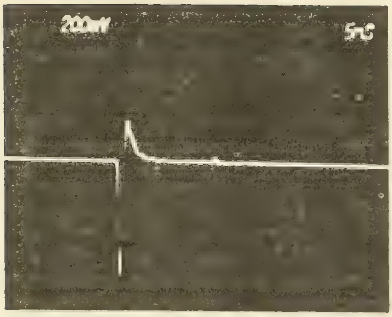


Fig. 14. Single bunch signal obtained form a beam position monitor.

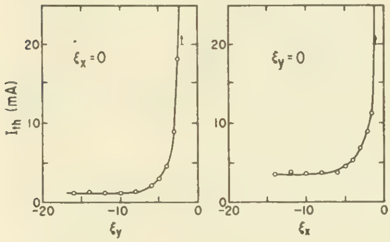


Fig. 15. Threshold currents of the head-tail instability. (a) ξ_y -dependence (ξ_x = 0). (b) ξ_x-dependence (ξ_y = 0).

3. Vacuum and beam lifetime

In spring shutdown of 1983, new controllers for BA-gauges were developed and installed. Then, data on vacuum pressure from 48 gauges could be taken by the aid of a micro-computer, with which a spatial distribution of the pressure and a time variation of average pressure as well as the stored current and the beam lifetime could be read on a visual display terminal.

As shown in Fig. 16, beam-cleaning of vacuum chambers has progressed with increase in the integrated stored current which is equivalent to the irradiated dose on vacuum chamber walls. Consequently, the improvement of beam lifetime has been progressed steadily, as seen in Fig. 17. In these figures, circles represent data in the spring run (May to July 1983), squares in the autumn run (October to December 1983) and triangles in the winter run (January to March 1984). Filled triangles correspond to the operation of the wiggler magnet.

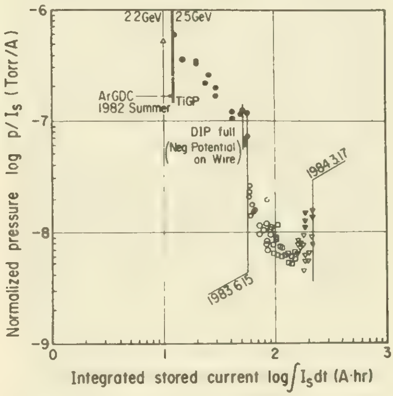


Fig. 16. Beam cleaning effect of the ring vacuum chamber.

In the latter half of the winter run, however, the lifetime was rather deteriorated because of bad vacuum condition in RF cavities, which was turned out to be due to very slow leak from one of the cavities. In addition, when the vertical wiggler magnet was in operation, the pressure rose up to 1 × 10^{-8} Torr locally, while it was kept below 1 × 10^{-9} Torr in the other part of the ring. This is because intense X-rays irradiated absorbers on the top and bottom of the downstream vacuum chamber, which were virgin surfaces to photon irradiations.

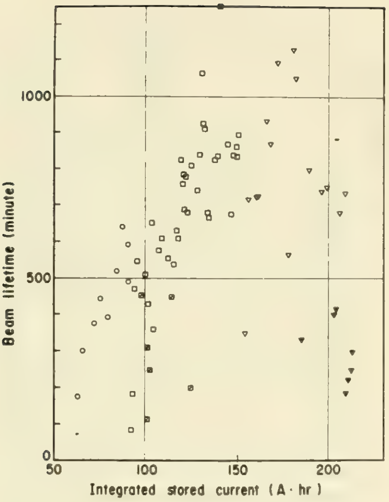


Fig. 17. Improvement in the beam lifetime with the integrated stored current.

4. Partially filled mode operation

In the uniformly filled mode operation, we observed a vertical instability as regular spikes in the signal of the beam profile monitor as seen in Fig. 18. This instability occurred at a stored current above 40 mA, but this did not lead to beam loss. This vertical pulsation was clearly correlated to the vacuum condition; for instance, the frequency of the pulsation increased with the average vacuum pressure in the vacuum chamber. The most likely interpretation for these phenomena is that positive ions trapped by the beam give rise to the instability.

Therefore, we expected that the trapped ions can be free from the attractive potential during the population gap in the circumference, if the ring was filled partially like a photograph in Fig. 19. In fact, the operation in this mode has succeeded in eliminating the vertical pulsation. The beam became apparently stable at some set of machine parameters. At a different set of parameters, however, we observed a different type of vertical instability which caused beam loss.

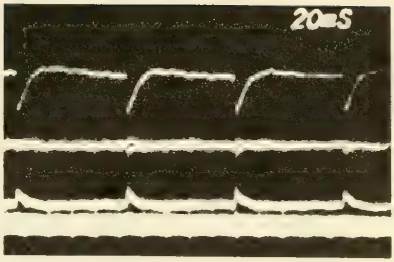


Fig. 18. Signal indicating the vertical instability observed in the uniformly filled mode operation.

The vertical blow-up appeared irregularly and the growth time was of order of 10 ms. It seems that the vertical instability has a threshold in the current per bunch at roughly 1 mA/bunch.

Fig. 19. An example of the population distribution in the partially filled mode operation.

By varying the currents of the defocusing sextupole magnets (SD), the defocusing quadrupole magnets (QD), and the focusing quadrupole magnets (QF), we found that there was a stable region in the $\xi_u - \nu_y$ plane, as shown in Fig. 20. Although the stable region seems to have a dependence on the population distribution, the vertical instability observed in the partial filling case was suppressed practically by exciting the sextupole magnets.

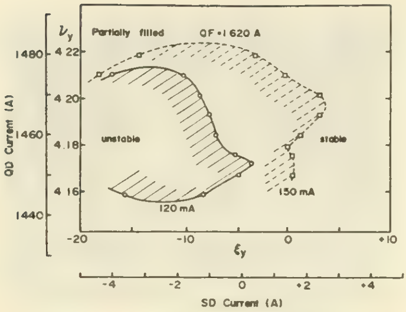


Fig. 20. Dependence of the vertical instability on the vertical betatron tune and chromaticity.

5. Cure for the instabilities

If the operating temperature of the accelerating cavities is changed by means of varying the dissipation power in the cavities or the temperature of cooling water, the resonant frequencies of the higher order modes of the cavity shift, while the accelerating mode is tuned correctly by the tuning plunger.

We have observed two coupled bunch instabilities which are caused by the higher order mode resonances of the cavity; the longitudinal coupled bunch instability by the TM011-like mode (758 MHz) and the horizontal coupled bunch instability by the TM111-like mode (1070 MHz). Frequency dependences of the threshold current of these instabilities were already investigated at a standard cavity temperature, which is given by cooling water temperature of 25°C, and cavity dissipation power of 22 kW in each cavity.

For the vertical wiggler operation, we have to increase the cavity dissipation power by 30 % to insure a sufficient quantum lifetime. This causes the cavity temperature rise, which leads to shift of unstable regions. Therefore, we have lowered the cooling water temperature by 5°C to avoid the unstable region of the horizontal coupled bunch instability, because this causes beam loss. At present, however, we still have the longitudinal coupled bunch oscillation, which causes no beam loss but accompanies the horizontal beam size modulation with frequency of about 200 Hz. Present regulation of water temperature has an error of 1°C. As a result, horizontal beam size changes in accordance with water temperature, because the threshold of the longitudinal instability fluctuates with the cavity temperature. This sometimes causes decrease of the beam lifetime at the operation of the vertical wiggler, in which the beam-stay-clear is narrow horizontally. For cure of the instabilities, we are planning to construct a new regulation system for the water temperature and also to insert higher order mode dampers to the cavities. We already finished fundamental test of the damping antenna with the low RF power. For the high power test, two damping antennae were built and test with RF power of 40 kW is progressing.

6. Beam channel development

In the spring shutdown of FY 1983, the front ends of four beam lines (BL-1, BL-2, BL-4 and BL-14) were installed. BL-1, intended for studies of microlithography and photochemical reactions, was constructed as a joint work between the Photon Factory and the Electrical Communication Laboratory, Nippon Telegraph and Telephone Public Corporation. BL-4 is the third X-ray beam line from a normal bending magnet. Three double beryllium window assemblies with horizontal apertures of 4.5, 6 and 6 mrad are connected at the downstream termination of the front end. Unlike previously constructed BL-10 and BL-15, branch beam shutters as well as the front end are installed inside the shielding wall, which has the advantage that a shielding hutch enclosing the branch beam shutters is unnecessary anymore. In consequence, experimental hutches could be set closer by a few meters to the shielding wall than in the other beam lines.

BL-2 is a beam line for a permanent magnet undulator installed in the long straight section between bending magnets B1 and B2. This line was designed to provide highly collimated undulator radiation for a single experimental station through a differential pumping section with small slits of 1 mm in diameter just outside the shielding wall. BL-14 is a beam line for a superconducting vertical wiggler installed in the medium straight section between bending magnets B13 and B14. A double beryllium window assembly transmits intense wiggler radiation to experimental stations. The window area is 16 mm in width and 90 mm in height and each beryllium foil is 0.3 mm in

thickness. In order to reduce the large thermal load produced by wiggler radiation, a 1 mm thick beryllium plate attached to a water cooled copper holder is placed in front of the window assembly.

INSTRUMENTATION DEPARTMENT

By the end of FY 1982, 15 experimental stations were made open to general users. These include stations for spectroscopic studies in the VUV and soft X-rays, EXAFS, X-ray topography, crystal structure analyses, small angle X-ray scattering and several kinds of diffraction studies in the hard X-ray region.

In FY 1983, major efforts were made to: (1) completion of beam lines and improvements in the experimental stations, and (2) full exploitation of all the operational stations.

In addition to the above-mentioned 15 stations, three new stations, which supply only white X-ray photons (BL-4), were made available in May, 1983. Performance tests of some newly-built monochromators were also carried out in FY 1983. These include, 1) a monochromator designed to achieve a very high resolution in the VUV region (BL-12B), 2) two kinds of monochromator which cover a wide soft X-ray energy region, one with a grating (BL-12C) and another with crystals (BL-11B), 3) a monochromator to obtain a point-focused beam with high photon flux (BL-11C), 4) two double crystal monochromators for hard X-rays (BL-4C and BL14A). They were almost ready for use by the end of FY 1983.

Successful operation of the vertical wiggler with high current and reasonable lifetime enabled us to use intense hard x-ray photons. The wiggler beam line (BL-14), with three branch stations, was constructed, and several preliminary experiments, such as X-ray imaging for diagnosis (X-ray angiography), diffraction topography of GaAs crystals, and so on, were performed at these stations.

In FY 1983, the Photon Factory Program Advisory Committee approved 103 proposals from users associated with universities and national institutes. The number of registered users in FY 1983 was 704, which is almost double that of the last fiscal year. 1356 hours were available in FY 1983 for users' experiments which are reported in the following sections.

Development of Beam Lines and Experimental Stations

1. X-ray beam lines

Installation and alignment of beam line components for BL-4 were made in April and May, 1983. This beam line is divided into three branch-lines, each intended initially as white X-ray stations. Approximately 15 experiments were carried out on these white beam stations.

A new monochromator was designed and built for BL-4C by March 1984. This monochromator will have a bent second crystal which sagittally focuses the beam horizontally.

Fundamental components of the vertical wiggler beam line had been installed and aligned by the end of October, 1983. The X-ray beam from the vertical wiggler was led into this beam line for the first time in December, 1983. An X-ray beam having 9 mrad vertical divergence is extracted from this beam line. This beam line is divided into three branch lines.

BL-14A is equipped with a double crystal monochromator, followed by a bent cylindrical mirror. This monochromator has three independent motions, i.e., a rotation of the first crystal and a rotation and translation of the second crystal. These three motions are synchronously controlled by a computer so that the monochromatized beam position is kept constant while the wavelength of the beam is scanned. The separation between the incident beam and the successively reflected beam is designed to be 45 cm, in order to have enough space for installing a four-circle diffractometer in the experimental hutch at the end of

this branch line. The four-circle diffractometer will be used mainly for protein crystallography.

For BL-14B, a double-crystal monochromator is being designed. This branch line will be used for precision diffraction experiments, such as standing-wave experiments and measurement of magnetic scattering.

BL-14C is used mainly for experiments of topography and X-ray angiography.

2. VUV and soft X-ray beam lines

Installation of a 6.65 m off plane Eagle type normal incidence monochromator (BL-12B) was completed at the end of FY 1982. This was designed to achieve the highest possible resolution for the VUV region (8 eV ~ 30 eV) and is composed of a predispersion system and an off-plane Eagle mount main monochromator. Optical and mechanical adjustments and several preliminary absorption measurements of simple gases were performed during FY 1983. Special care was taken to reduce the vibration and temperature changes during the measurement. After a struggle of adjustments, we obtained almost satisfactory absorption spectrum of O_2 gas. Figure 21 shows the absorption spectrum of the O_2 Schuman-Runge band near 1800 Å, photographed on an SWR plate. It is found through this spectrum that the resolving power is almost 200,000, which is comparable with the highest previous value in the world.

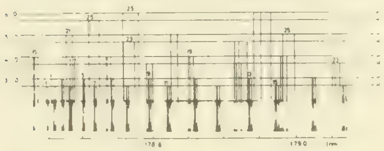


Fig. 21. Absorption spectrum of O_2 Schumann-Runge band system photographed in the third order with 6 VOPE.

Two kinds of monochromator, which cover over a wide energy range in the soft X-ray region, were installed at the end of FY 1982, and performance tests of these monochromators were carried out during machine time in FY 1983.

One is a 10 m Rowland circle grazing incidence monochromator (BL-12C), and another is a UHV compatible double crystal monochromator (BL-11B). The former was designed to provide high-resolution monochromatic photons in the soft X-ray range from 500 eV to 2000 eV. The resolution obtained was about 0.004 Å using a 2400 ℓ/mm grating with a slit width of 5 μ.

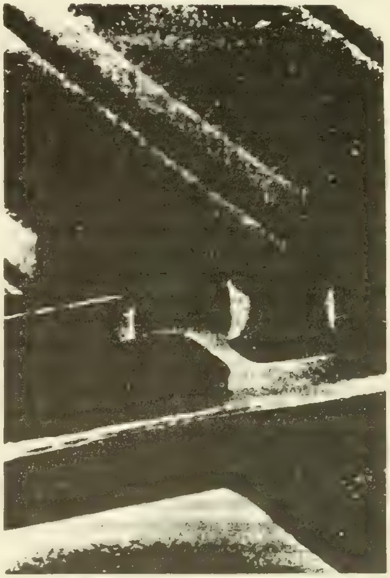


Fig. 22. An example of test pattern obtained at BL-1B X-ray lithography station. In this trial, lines 0.2 μm wide by 1.0 μm high could be produced. (Courtesy Nippon Telegram and Telephone Cooperation.)

The latter instrument employs beryl (10$\bar{1}$), α-quartz (10$\bar{1}$0) and Ge (111) as monochromatizing crystals they are *in-situ* interchangeable. A pair of beryl crystals covers the photon energy range from 800 to 1500 eV, while α-quartz and Ge crystals cover from 1450 to 3500 eV, and from 2000 to 4000 eV, respectively. Through measurement of rocking-curve widths for each pair of crystals we found that the spectral resolution is better than 1 eV over the available photon energy range.

An NTT (Nippon Telegram and Telephone) Coop-

eration group has carried out preliminary experiments for X-ray lithography at their own beam line (BL-1) and proved that synchrotron radiation is a promising light source for fabricating very large scale integrated (VLSI) circuits. A typical result is shown in Fig. 22.

Experimental Programs

On already-existing and newly-developed experimental stations, approximately 80 kinds of experiments have been carried out in FY 1983. Most of these experiments would not have been realized if synchrotron radiation were not available. Only a limited number of examples are described here:

1. Dynamic structural study of materials

Since synchrotron radiation is very intense, the time required for data collection can be shortened by many orders of magnitude, if an appropriate data collecting system is available. This opens up the possibility of time-resolved or dynamic study of structural or chemical changes in materials upon some excitation or stimulation of the sample.

(a) Time-resolved small angle X-ray diffraction experiments from muscle

During the contraction of muscle, the periodic structure of fibers constituting the muscle changes with time. By observing the time dependence of a small angle X-ray diffraction pattern from this periodic structure, we can understand the molecular mechanism of muscle contraction. Such time-resolved measurements have been done, to a some extent, with high brightness rotating-anode X-ray sources.

Recently, in order to obtain a better understanding of the mechanism of muscle contraction, a more detailed time-resolved study of weaker reflections was proposed. However, for these weak reflections, time-resolved observations had been impossible. A group from Osaka Univ., Teikyo Univ. and the Photon Factory succeeded in making time-resolved measurement of such a weak reflection using the Small Angle X-Ray Scattering instrument on BL-15A. They observed meridional reflections from thin filaments of frog muscle, which are one order of magnitude weaker than those from thick filaments (Fig. 23). This small angle scattering instrument can of course be used for materials studies also, and several groups have made studies of amorphous materials, or metal samples.

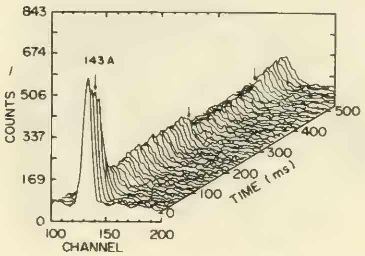


Fig. 23. Time dependent variation of small angle X-ray diffraction pattern (the weak meridional reflection) from a flog-muscle after a stimulus is given.

(b) Dynamic observation of chemical reactions by X-ray absorption spectroscopy

In a conventional method of measuring the X-ray absorption spectrum, each data point is taken successively in a point-by-point mode by changing the energy of the X-ray beam. Hence, the data collection time is usually 20 - 30 minutes, even with synchrotron radiation. Most has therefore been limited to static samples. In an energy dispersive mode, where convergent X-ray beams have a one-to-one correspondence between energy and the converging angle of each beam, the entire spectrum can be taken simultaneously in less than 0.1 seconds. A group from the Photon Factory, the Electrotechnical Laboratory, and Jichi Medical School has recently made dynamic observation of the reaction of two aqueous solutions mixed using a stopped-flow method. They mixed solutions of $Fe(NO_3)_3$ with $Na_2\ S_2\ O_3$, and observed the time-dependent shift of the Fe K absorption edge due to the transition from Fe^{3+} to Fe^{2+}, as shown in Fig. 24. Such a method can be applied to various dynamic systems.

2. Structural study under high pressure and high temperature

A large group of high pressure physicists constructed a diffractometer which is capable of performing diffraction experiments under high pressure (up to 200 Kbar) and high temperature (up to 1500°C), in

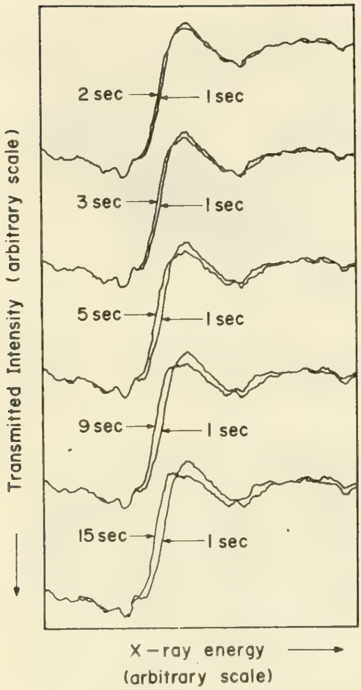


Fig. 24. Time dependent shift of Fe K absorption edge after mixing two solutions of Fe $(NO_3)_3$ and $Na_2S_2O_3$ by stopped flow-method.

the energy dispersive mode. Because the sample cell has to be relatively thick and strong to keep the sample under such high pressure and high temperature, the X-ray diffraction experiment has been relatively difficult owing to the absorption of X-rays by the sample cell materials. With intense synchrotron radiation, however, such measurements became much easier, and new categories of experiments have been started. Approximately 10 subjects were studied using this high pressure high temperature instrument. An example is the *in-situ* observation of the transition from graphite to diamond, as shown in Fig. 25.

In this experiment, first, the pressure was raised up

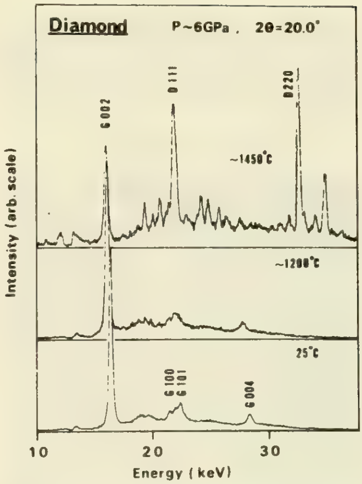


Fig. 25. X-ray diffraction profiles in the course of graphite to diamond transformation. G denotes the peaks of graphite and D denotes those of diamond.

to 60,000 atmospheric pressures, then the temperature was slowly elevated. At about 1450°C, the intensity of diffraction peaks for graphite suddenly decreased and new peaks corresponding to the formation of diamond appeared. It was also found that peaks due to the formation of Fe_3C were found. Even though this study is in its early phase, such in-situ observation were made for the first time.

3. Detection of impurity atoms of ppb order

X-ray fluorescence analysis has long been used as a non-destructive method of element analysis. The sensitivity has been relatively, however, compared with other destructive methods, such as atomic absorption spectroscopy and neutron activation analysis. However, with use of synchrotron radiation, several orders of magnitude improvement has been attained in the detection limit of the fluorescence method. Now, at the Photon Factory, a detection limit of ppb order in a relative scale or several pico grams in an absolute scale has been attained. In order to obtain such a high sensitivity, special care was taken to reduce the back-

ground. The sample is supported on an optically-flat substrate, by which the external total reflection of the incident X-ray beam occurs. With such an arrangement, the background intensity is reduced by a few orders of magnitudes compared with the conventional arrangement where the incident beam is incident on the sample at an angle of about 45°.

The types of samples studied hitherto were rather diverse: metal impurities in an SiO_2 insulating film on a silicon wafer, implanted ions in a silicon wafer, metal elements in human hair, metal impurities in water, metal elements in a rat-organs.

4. X-ray topographic in-situ observation of crystal-melt interface of Gallium Aresenide single crystal

Gallium arsenide is expected to be a next generation material for semiconductor industry because of its large electron mobility, so that production of very perfect crystal is anticipated. For growing good crystals, understanding of defect creation at the crystal-melt interface is very important. With X-ray topographic method utilizing X-ray sensitive TV-camera, *in-situ* observation of creation of defects at the crystal-melt interface was made on BL-15B. Figure 26 shows topographic images of a GsAs crystal at room temperature, 1245°C and 1260°C. It is known that perfection of GaAs crystal depens on the As-pressure during crystal growth. *In-situ* X-ray topographic method will be very useful for getting further understanding of the mechanism of growth of perfect crystal.

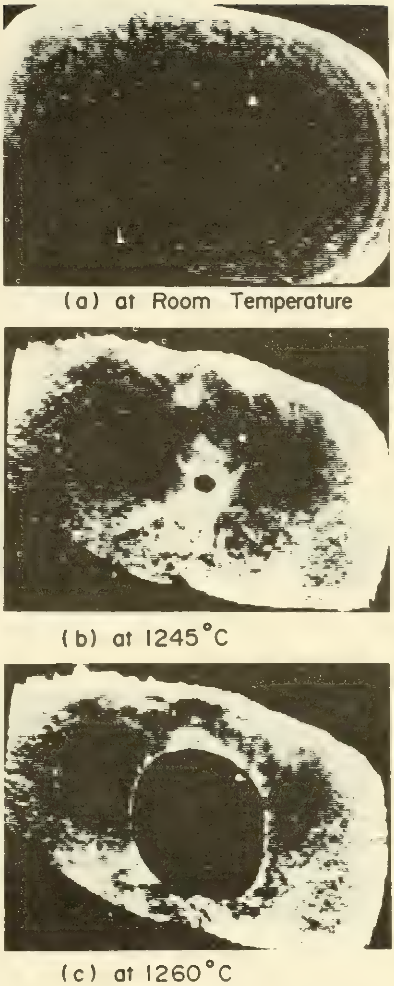


Fig. 26. Real-time X-ray topographic images of GaAs single crystal obtained by X-ray sensitive TV-camera. The black parts in the center of the crystal in (b) and (c) are melt part of the crystal. White contrast at the crystal-melt interface reflects creation of lattice defects.

5. Medical imaging using monochromatic synchrotron X-radiation

A development program has been initiated during FY 1983 to develop medical imaging techniques using monochromatic synchrotron radiation. Monochromatic radiation is useful in enhancing the contrast of images formed by blood vessels and organs into which contrast material (Iodine) is introduced. By obtaining two images, with X-ray energies below and above the K-absorption edge of Iodine, and by subtracting one image from the other, unwanted images by the rest of the body, such as bones, can be eliminated. Figure 27 shows X-ray pictures of rat kidney and blood vessel into which Iodine is injected. It is clearly seen that the image of bone disappeared in the subtracted image. If the present technique is successfully developed, the ne-

Fig. 27. X-ray images of rat kidney and blood vessel into which Iodine is injected as a contrast material. Unwanted images by bones and other organs almost disappear in the subtracted image.

cessity to use unpleasant catherters in injecting iodine into heart is eliminated. Thus the examination would become much easier and less expensive.

6. Measurement of the mass of the electron neutrino

It has been an earnest desire of physicists to determine an accurate value of the electron neutrino mass, $m_{\nu e}$. A joint group, consisting of members from the Physics Department and Photon Factory of KEK, Tohoku Univ. and 5 other universities have challenged this problem by studying the electron capture in ^{163}Ho. In determination of both $m_{\nu e}$ and Q value simultaneously, it is essential to measure the exciting photon energy dependence of the $M_{4,5}$ fluorescence yields of Dysprosium.

Such an experiment was performed using monochromatized soft X-rays at the undulator beam line (BL-2). The resulting values of $m_{\nu e}$ and Q are 245 $\pm$ 500 eV and 2.56 $\pm$ 0.27 keV, respectively.

7. Atomic structure of the interface between silicon and nickel silicide

In this example, the usefulness of the standing wave formed near the surface of a perfect crystal upon Bragg reflection is shown. Determination of the atomic structure of the interface between two crystalline materials by X-ray techniques has been an interesting but relatively-difficult problem. With a new analysis technique, called the Standing Wave Method, a great technical improvement has been made. The method makes use of the X-ray standing wave formed near the surface of a perfect crystal upon Bragg reflection. The period of the standing wave along the normal to the diffracting lattice plane is equal to that of the lattice plane. The phase of the standing wave can be varied from 0 to π by changing the deviation angle of the incident X-ray beam, so that the fluorescence yield from an atomic element of interest becomes a maximum when the anti-node of the standing wave coincides with the position of the element. By measuring the angle dependence of such a fluorescence yield and by comparing the experimental curve with calculated ones based on model structures of the interface, we can determine the atomic structure of the interface. Figure 28 shows the fluorescence yield from nickel in nickel silicide on a silicon single crystal substrate. Curves "I" and "II" are derived from two model structures "I" and "II" for the inter-

face. As can be seen in the figure, the agreement between the experimental curve and curve "I" is very satisfactory, resulting in the conclusion that the model structure "I" is a realistic structure.

8. Electronic structures of metal vapors

In general, electronic structures of atoms in the gas phase are entirely different from those in the solid metal phase. We developed a special furnace to produce metal vapors, and measured absorption spectra of Cs and Ba as well as Xe around 3d threshold, using the Grasshopper monochromator. The broad 3d → ε absorption bands of Xe change into sharp 3d → 4.5 absorption lines for atomic Ba (see Fig. 29), clearly manifesting the collapse of the f-symmetric final-state wave function for 3d excited Ba.

Relative photoionization cross section of Ca around the 3p threshold was also measured at the Seya-Namioka station (BL-12A) by use of the same furnace. Comparison with the photoabsorption data shows a good correspondence in the peak structure between the absorption resonance and the Ca^{2+} yield for photon energies above the lowest 3p ionization limit. This indicates an enhancement of double photoionization by two-step autoionization mediated via Ca^{+} 3p hole states.

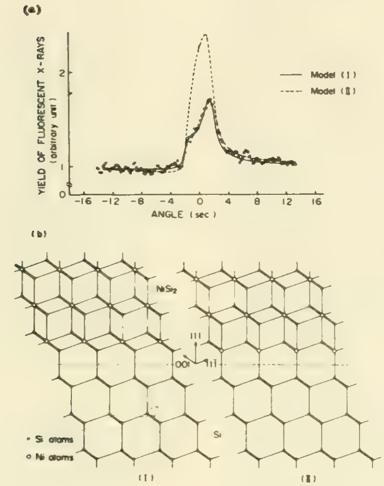


Fig. 28. Fluorescence yield from nickel in nickel silicide on a silicon single crystal substrate (a) and two model structures for the interface (b). Calculated curve based on the model (I) agrees well with the experiment.

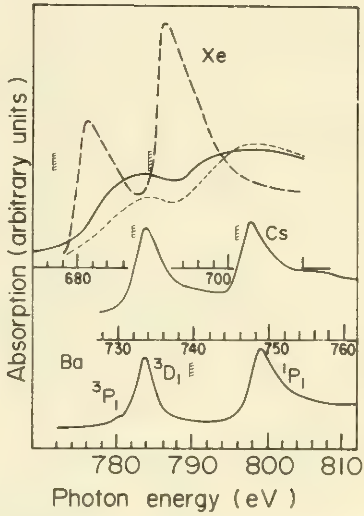


Fig. 29. Experimental absorption cross section (full curve) of atomic Xe, Cs and Ba at the 3d threshold. For Xe, results of calculations in the one-electron HF approximation (broken curve) and in the generalised RPAE approximation (dotted curve) are included.

Appendices

APPENDIX A

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APPENDIX B

KEK Colloquia

Laboratory Colloquia

WU, C.S. (Columbia Univ.) An experimental review on the double beta decay	April 7, 1983
OZAKI, Satoshi (KEK) Review on TRISTAN and high energy accelerators in the world	April 22, 1983
RUBBIA, Carlo (CERN) On the production of $W^{\pm}$ and Z^0 bosons in the UA1 experiment at CERN SPS	June 18, 1983
OZAKI, Satoshi (KEK) Reports on 1983 International Symposium on Lepton and Photon Interactions at High Energies	September 28, 1983
KAMEI, Tohru (KEK) Report on the 12th International Conference on High-Energy Accelerators	September 28, 1983
KIKUCHI, Ken (KEK) Trip report to high energy laboratories in the U.S. (SLAC, LBL, FNAL and BNL)	February 3, 1984
ARAI, Terutaka (KEK) Trip report to high energy laboratories in the U.S.	February 3, 1984

Meetings

ACCELERATOR DEPARTMENT

5th Meeting on Ultrahigh Vacuum Techniques for Accelerators and Storage Rings	March 26-27, 1984

PHYSICS DEPARTMENT

8th Workshop on the Mass of the Electron Neutrino	September 7, 1983
Grand Unified Theory and Cosmology	December 7-10, 1983
9th Workshop on the Mass of the Electron Neutrino	January 19, 1984
Workshop on Hyper Nuclear Physics at KEK-PS	January 21-23, 1984
Physics on Fancy Spectrometer	February 27-29, 1984
Future High Energy Accelerators and Physics	March 27-30, 1984

BOOSTER SYNCHROTRON UTILIZATION FACILITY

Annual Meeting on Neutron Scattering at KEK	March 1-3, 1984
Meeting on BSF Future Prospects - III	March 1-3, 1984

PHOTON FACTORY

1st Photon Factory Symposium	November 4-5, 1984

APPENDIX C

List of Publications

KEK Publications

Annual Report
KEK Annual Report 1982 (April, 1, 1982 - March 31, 1983).

KEK Progress Report 83- 1
Photon Factory Activity Report, 1982/1983.

KEK 83- 1 A
Ikegami, K., Mori, Y., Takagi, A. and Fukumoto, S.: Characteristics of 6.5 GHz ECR ion source for polarized H^- ion source. (in Japanese)

KEK 83- 2 P
Meeting on Synchrotron Radiation X-ray Scattering Study of Nonequilibrium Systems: Proceedings, ed. by Y. Fujii and T. Matsushita. (in Japanese)

KEK 83- 3 A/P
Yamazaki, Y., Kobayakawa, H., Kamiya, Y. and Kihara, M.: A transverse coupled bunch instability observed in the KEK-PF electron storage ring.

KEK 83- 4 TRISTAN(I/E)
Report of Meeting on New Detectors for High Energy Physics, KEK, Tsukuba, Japan, December 2-4, 1982: ed. by H. Iwasaki, and T. Sumiyoshi.

KEK 83- 5 A/P
Kihara, M., Kamiya, Y., Kobayakawa, H., Yamazaki, Y., Kobayashi, M., Kitamura, H., Shibata, S., Kajiura, N., Katsura, T., Pak, C.O., Sato, S., Koide, T., Kanaya, N., Yamakawa, T., Araki, A., Tokumoto, S., Takiyama, Y., Igarashi, T., Mishina, A., Shioya, T. and Huke, K.: Results on accelerator studies of the Photon Factory Storage Ring — Phenomenological review —.

KEK 83- 6 I/T/E
Workshop on Hyper Nuclear Physics, KEK, November 25-27, 1982: Proceedings, ed. by T. Yukawa. (in Japanese)

KEK 83- 7 A/P
Yamazaki, Y., Kobayakawa, H., Kamiya, Y. and Kihara, M.: A longitudinal coupled bunch oscillation observed in the KEK-PF electron storage ring.

KEK 83- 8 A/P
Kobayakawa, H., Yamazaki, Y. and Kamiya, Y.: Measurement of damping time and frequency of coherent synchrotron oscillation in PF storage ring.

KEK 83- 9 A/P
Kobayakawa, H. and Yamazaki, Y.: The tuner control system for the PF cavity.

KEK 83-10 E
Bruyant, F.: Off-line software for large experimental setups.

KEK 83-11 TRISTAN(E)
Tominaka, T., Takasaki, M., Wake, M. et al.: Quench simulation in the thin superconducting solenoid.

KEK 83-12 T/E
Workshop on "Monopoles and Proton Decay", Kamioka, Japan, October 18-20, 1982: Proceedings, ed. by J. Arafune and H. Sugawara.

KEK 83-13 T
Workshop on Grand Unified Theories and Early Universe, KEK, Tsukuba, Japan, January 25-27, 1983: Proceedings, ed. by M. Fukugita and M. Yoshimura.

KEK 83-14 A/I
Ishii, K.: Digital delay CAMAC module with 550 MHz preset counter (TD-2).

KEK 83-15 E
7th Workshop on the Mass of the Electron Neutrino: Proceedings, ed. by S. Yasumi. (in Japanese)

KEK 83-16 A/P
Kamiya, Y. and Kihara, M.: On the design guideline for the low emittance synchrotron radiation source.

KEK 83-17 A/P
Yamazaki, Y., Kihara, M. and Kobayakawa, H.: Partially filled multi-bunched mode operation of the Photon Factory electron storage ring and cure of the vertical instability.

KEK 83-18 TRISTAN(A)
Grobner, O., Momose, T., Mizuno, H., Kobaya-

shi, M., Kanazawa, K., Horikoshi, G., Narushima, K. and Ishimaru, H.: Gas desorption and photo-electron production from aluminum exposed to synchrotron radiation.

KEK 83-19 A
Chin, Y.: The wake field acceleration using a cavity of elliptical cross section, part I: WELL (A computer code for wake fields in a cavity of elliptical cross section).

KEK 83-20 TRISTAN(A)
Higo, T.: Calculation of the TE_0 mode by the extended version of SUPERFISH.

KEK 83-21 A
Symposium on Ion Source in Accelerators, KEK, Tsukuba, Japan, March 15-16, 1983: Proceedings, ed. by S. Fukumoto and Y. Mori. (in Japanese)

KEK 83-22 P
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APPENDIX D

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DESY JOURNAL

1959-1984

DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY HAMBURG

25 Jahre

Sonderausgabe über die Fest- und Informationswoche zum 25jährigen DESY-Jubiläum

Special Edition on the Occasion of the Ceremony of the 25th Anniversary of DESY

Nr. 3/4
Dezember 1984

Texte auf deutsch und englisch
Text in German and English

DESY Journal 84-3/4 Inhalt / *Contents*

1984 existiert das Deutsche Elektronen-Synchrotron in Hamburg 25 Jahre; das genaue Gründungsdatum ist der 18. Dezember 1959. Aus diesem Anlaß veranstaltete DESY vom 24. bis 29. September eine Fest- und Informationswoche. In Anwesenheit des Bundespräsidenten wurde sie mit einem Festakt eingeleitet; Persönlichkeiten aus Politik und Wissenschaft feierten dieses Jubiläum zusammen mit der DESY-Belegschaft, den Gastwissenschaftlern und vielen anderen, die an der Geschichte DESYs mitgewirkt haben. Unter ihnen waren auch die vier Vorsitzenden des DESY-Direktoriums der vergangenen 25 Jahre: Das Titelbild zeigt von links nach rechts Willibald Jentschke, Wolfgang Paul, Herwig Schopper und Volker Soergel.

1984 is the year of the 25th anniversary of the Deutsches Elektronen-Synchrotron DESY in Hamburg; the exact founding day was the 18th December 1959. On this occasion DESY arranged a celebration and information week, 24th to 29th September. It was started in the presence of the Bundespräsident. Personalities from politics and science celebrated this anniversary together with the DESY staff, the guest scientists and many others, who contributed to the history of DESY, among them the four chairmen of the DESY Directorate from the past 25 years. The cover picture shows (from left to right) Willibald Jentschke, Wolfgang Paul, Herwig Schopper and Volker Soergel.

Foto DESY Jürgen Schmidt (37900/13)

Begrüßung durch

Prof. Volker Soergel
Vorsitzender des DESY-Direktoriums

Herr Bundespräsident,
Herr Präsident der Bürgerschaft,
Herr Bürgermeister,
Exzellenz,
verehrte Gäste,
liebe Mitarbeiterinnen, liebe Mitarbeiter!

Ich begrüße Sie alle sehr herzlich zu unserer heutigen Feier, bei der wir das 25jährige Bestehen von DESY begehen wollen. Vor 25 Jahren, und zwar genau am 18. Dezember 1959, wurde hier in Hamburg, im Rathaus, der Vertrag zur Gründung der Stiftung "Deutsches Elektronen-Synchrotron" feierlich unterzeichnet. Stifter waren die Bundesrepublik Deutschland und die Freie und Hansestadt Hamburg, und sie waren damals vertreten durch den Bundesminister für Atomenergie und Wasserwirtschaft, Siegfried Balke, und Bürgermeister Max Brauer.

Dieses für DESY so wichtige Ereignis wollen wir heute gemeinsam begehen. Es ist für uns eine hohe Ehre und eine große Freude, daß wir Sie, Herr Bundespräsident, heute bei uns begrüßen dürfen, daß Sie gekommen sind, um mit uns dieses festliche Ereignis zu begehen und zu uns zu sprechen. Ich begrüße Sie herzlich zu diesem Ihrem ersten Besuch bei DESY, und wir danken Ihnen alle sehr für Ihr Kommen.

Mein besonderer Gruß gilt Herrn Prof. Panofsky, der heute aus Kalifornien zu uns gekommen ist, um den Festvortrag zu halten. Wir sind sehr glücklich, Sie hier bei DESY heute wieder einmal begrüßen zu können.

Im übrigen bitte ich um Entschuldigung, wenn ich die Begrüßung jetzt summarisch halte, weil wir etwas im Verzug sind mit der Zeit. Ich freue mich, daß viele unserer Einladung gefolgt sind, heute mit uns zu feiern. Ich heiße Sie alle herzlich willkommen.

Ich bitte nun den Herrn Bundespräsidenten, zu uns zu sprechen!

Welcome from

Prof. Volker Soergel
Chairman of the DESY Directorate

Herr Bundespräsident,
Herr Präsident der Bürgerschaft,
Herr Bürgermeister,
Your Excellency,
Honoured Guests,
Dear Colleagues!

I welcome you all to our celebration of the 25th anniversary of DESY today. 25 years ago, on the 18th December 1959 to be exact, the contract to found the institute "DESY, Deutsches Elektronen-Synchrotron" was ceremonially signed in the Hamburg Rathaus. The sponsors were the Federal Republic of Germany and the Freie und Hansestadt Hamburg, and they were represented on that occasion by the Minister of Atomic Energy and Water Supply, Siegfried Balke, and the Hamburg Bürgermeister, Max Brauer.

Today we want to celebrate together this most important occasion for DESY. It is a great honour for us and a great pleasure to welcome you here, Herr Bundespräsident, to celebrate this event with us and to address us. I heartily welcome you to this, your first visit to DESY and we all thank you that you have come.

A special greeting must also go to Prof. Panofsky, who arrived here today from California to hold the celebratory lecture. We are very happy to welcome you here once again.

I apologize if I stop my welcome now, because we are somewhat behind with the time. I am very pleased that so many people have accepted our invitation to celebrate with us today. You are all very welcome.

Now I ask the Bundespräsident to address us.

Grußansprache von

Bundespräsident Dr. Richard v. Weizsäcker

Herr Vorsitzender,
Herr Bürgermeister,
meine Damen und Herren!

Ich bin ein Pünktlichkeitsfanatiker. Um so härter trifft es mich, daß ich, obwohl pünktlich über Hamburg angekommen, doch nicht rechtzeitig landen konnte. Wir sind 45 Minuten über Hamburg gekreist. Das war schön - aber Sie mußten warten, und ich bitte Sie dafür vielmals um Entschuldigung. Im übrigen ist es ja irgendwo auch ein Stück ausgleichender Gerechtigkeit oder innerer Beruhigung, daß man sich anschickt, in das Herzstück der Grundlagenforschung vorzustoßen, um herauszufinden, was die Welt im Innersten zusammenhält, aber an einem kleinen watteähnlichen Nebel scheitert, wenn man pünktlich landen will.

DESY ist wie immer seiner Zeit voraus, es hat uns etwas verfrüht zu seinem 25. Geburtstag eingeladen. Ich bin gern gekommen, nicht um zu würdigen, was hier geleistet worden ist und geleistet werden wird - das steht mir nicht zu. Das Prinzip der Arbeitsteilung, das Sie in der Hochenergiephysik kennen, gibt es auch unter Brüdern - und um über Ihre Arbeit zu urteilen, haben Sie den falschen Bruder gewählt. Ich bin aber gekommen, um mich zu informieren, um DESY besser kennenzulernen und um mich den Gedanken über den Rang der Grundlagenforschung zu stellen, die mich, die uns alle zutiefst etwas angeht.

Es ist ja nicht uncharakteristisch für die tiefgreifenden geistigen Veränderungen in unserer Zeit, daß der Mensch, den man etwas pauschal und ungenau gebildet nennt, wesentliche Erkenntnisse der Naturwissenschaft heute nicht mehr ohne weiteres in seinen Fundus, in seine von ihm selbst kritisch überprüfbare Ansammlung von Wissen und Weltsicht integrieren kann. Er steht nicht mehr vor bloßen

Address from

Bundespräsident Dr. Richard v. Weizsäcker

Mr. Chairman,
Herr Bürgermeister,
Ladies and Gentlemen!

I am a punctuality fanatic. It therefore pains me particularly that although I arrived punctually over Hamburg, it was not possible to land on time. We circled over Hamburg for 45 minutes. That was very nice - but you had to wait - and I apologize for that. It seems to be perhaps poetic justice or at least inner reassurance, that one comes to penetrate into the heart of basic research, to find out what holds the world together, and is thwarted by a small bit of cottonwool-like fog when one wants to land punctually.

DESY is always somewhat ahead of its time; it has invited us somewhat too early to its 25th birthday. I am glad to have come, not to appreciate the value of what has been and will be achieved here - I'm not qualified for that. The principle of division of labour that you know in high energy physics also exists between brothers - and in order to be able to judge your work here, you have chosen the wrong brother. Rather I have come to inform myself, to get to know DESY better, and to prompt thoughts about the rank of basic research, which deeply affects us all to a certain extent.

It is not uncharacteristic of the deep mental changes in our time, that a human being, who one somewhat arbitrarily calls educated, cannot obtain a significant appreciation of science within his critically self-imposed collection of knowledge and perspective. He doesn't stand in front of simple gaps in his knowledge, which he could reasonably fill with the conventional method of learning, rather in front of areas which, at least that's what his feelings say to him, are shut off in principle to him. That which is

Wissenslücken, die er gewissermaßen mit den konventionellen Mitteln des Nachlernens füllen könnte, sondern vor Bereichen, die ihm, so sagt es ihm jedenfalls sein Gefühl, prinzipiell verschlossen zu sein scheinen. Was sich ihm verschließt - das, was diese Wissenschaft an Erkenntnis hervorbringt, wozu sie nutzt - aber empfindet er als unheimlich. Er sieht sich kaum in der Lage, dies kritisch nachzuvollziehen. Muß er es also den Wissenschaftlern, den Sachverständigen glauben? Das tut er natürlich auch ungern, zumal er weiß, daß es sich nicht um Glaubensdinge handelt.

Ich bewundere klare Köpfe mit gesundem Menschenverstand. Aber reicht das, um den Weg der Grundlagenforschung zu deuten? Viele von Ihnen kennen den Versuch von Sebastian Haffner, dies zu tun. Er hat über CERN geschrieben und geurteilt - sehr anregend und verdienstvoll, wie ich finde, mit dem Ziel, daß man sich mit der Grundlagenforschung auseinandersetzt, sie nicht einfach hinnimmt oder den Zustand hinnimmt, sie doch nicht mehr verstehen zu können. Aber weiß er damit, was Ihr Ziel, was das Ziel der Hochenergiephysik ist, für das Sie arbeiten? Kann man mit gesundem Menschenverstand und klarem Kopf sagen, daß es sich hier um Ziele handelt, die unerreichbar wären, vielleicht sogar gar nicht existent? Ich weiß es nicht. Ich will darüber auch nicht spekulieren, das ist nicht meines Amtes. Was ich aber zu sehen glaube, möchte ich so formulieren:

Grundlagenforschung, so scheint es mir, ist ihrem Wesen nach zunächst nicht in der Lage, vorab über Nutzen und Anwendung möglicher Ergebnisse Auskunft zu geben. Die bisherige Geschichte solcher Forschungen weist sowohl lohnende als auch vertane Arbeit auf und zu allermeist Überraschung. Das hat die Menschen nie daran gehindert, und es wird sie auch in Zukunft nicht daran hindern, weiter neugierig zu forschen, zweckfrei und wertfrei. Es ist sinnlos und entspricht weder dem Wesen der Wissenschaft noch dem Wesen des Menschen überhaupt, Grundlagenforschung prinzipiell mit dem Argument zu bekämpfen, ihr Ziel wäre unerreichbar

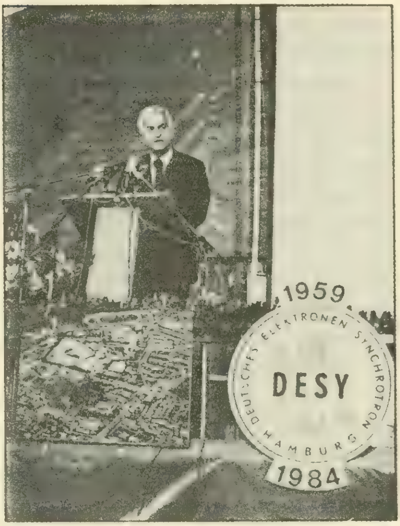


Foto DESY-PR Florian Becker

shut off from him - the knowledge of this science and what it can be used for - gives him a sinister feeling. He does not see himself in a position to critically judge it. Does he therefore have to believe the scientists, the experts? Naturally he is not too keen to do that, particularly as it is not just a matter of faith.

I admire clear heads with common sense. But is that sufficient to interpret basic research? Many of you know of the attempt of Sebastian Haffner to do this. He wrote about and judged CERN, which I found to be very stimulating and worthy. The aim was to grapple with basic research, not just to accept it, or to accept the situation that one can't understand it. But does he know what the target of high energy physics is which you are working towards? Can one say, with just common sense and a clear head, whether this target is unreachable, or perhaps doesn't even exist? I don't know and I don't want to speculate about it,

oder vielleicht nicht existent oder die Menschen könnten möglicherweise mit den Ergebnissen nichts anfangen.

Ergebnisse der Grundlagenforschung sind zunächst wertfrei. Sie können, wenn sie zutage treten, dem Menschen entweder nützen oder schaden. Dies ist auch ein wissenschaftliches Problem und zwar insofern, als Wissenschaftler, auch Grundlagenforscher, hier nicht einfach sagen dürfen, daß sie für die moralischen und die politischen Folgen nicht mehr zuständig seien. Sie, die Wissenschaftler, tragen in wachsendem, in hohem Maß ethische Mitverantwortung gerade für die Folgen der Wissenschaft. Mit Macht und mit Recht wird die Frage nach den ethischen Kriterien für Verwendung und Folgen wissenschaftlicher Leistungen immer lauter.

Nicht über den Sinn von solcher Grundlagenforschung also lohnt es sich zu streiten. Aber es ist unvermeidlich, über Kosten und über Prioritäten des Einsatzes öffentlicher Mittel zu reden, dies um so mehr dann, wenn die öffentlichen Ressourcen bis an ihre Grenzen beansprucht werden. Die Verantwortlichen von DESY wissen das ganz genau. Sie wissen, daß sie das Vertrauen der Gesellschaft brauchen. Man erhält dieses Vertrauen durch Leistungsnachweise und durch die persönliche Qualifikation derer, die diese Leistungen öffentlich vertreten. Unsere Gesellschaft mag in ihrer Breite nicht mehr in der Lage sein, schwierige wissenschaftliche Erkenntnisse nachzuvollziehen. Sie wird aber sehr wohl diejenigen beurteilen, die dies tun. Sie wird ihr Urteil auch danach ausrichten, wie die Wissenschaftler die gesellschaftlichen Folgen und die ethische Integration ihres Tuns zu reflektieren vermögen und verständlich machen können.

Dieser Vormittag und das ganze Jubiläum wird die Öffentlichkeit mit neuen Informationen über bisherige Ergebnisse sowohl bei DESY als auch prinzipiell in der Grundlagenforschung ausstatten. Der Zwang zur Begründung, die Anstrengung um Verständnis in der Öffentlichkeit ist notwendig und heilsam. Niemand wird die

that is not my function. I would like to formulate my observations as follows:

It seems to me that basic research is, in principle, not able to predict the uses and applications of possible results. The history of such research shows much worthwhile as well as worthless work and most of all surprises. That never has, and never will stop man from researching with curiosity and free of practical applications. It is nonsense and goes against the essence of science and humanity to argue against basic research on the principle that its aims are unreachable, or perhaps don't exist, or that one cannot do anything with the results anyway.

The results from basic research are first of all without application. The applications can, when they become evident, either be of use or harm to man. This is also a scientific problem to the extent that as scientists, fundamental researchers cannot simply say that they are no longer responsible for the moral and political consequences. They, the scientists, carry a large and growing ethical responsibility for the consequences of science. Questions on the ethical criteria for the uses and consequences of scientific achievements are, powerfully and correctly, becoming louder and louder.

It is therefore not worth arguing over the point of basic research. However, it is impossible not to discuss the priorities and costs for the use of public means; even more so when the public resources are strained to their limits. Those responsible at DESY know this. They know that they need the trust of society. One obtains this trust through the proof of achievements and from the personal qualifications of those who publish these results. Our society as a whole can perhaps no longer fully understand difficult scientific results. However, they will judge those who do this. They will also base their judgement on how well the scientists publish and make understandable the consequences for society and the ethical integration of their results.

wissenschaftlich Verantwortlichen von diesem Zwang befreien wollen. Aber ich denke, die verantwortlichen Wissenschaftler selbst werden dies auch gar nicht wollen. Sie werden selbst darauf bestehen, diese Anstrengungen zu leisten. Neben der Seele des Geschäftes, um das es hier geht, der Suche nach fundamentalen Prinzipien und Symmetrien in der Natur, stehen wesentliche Merkmale im Vordergrund, wenn wir an DESY denken und den 25. Geburstag feiern:

- die positive Breitenwirkung der Ausbildungsfunktion der Hochenergiephysik auf den gesamten Ausbildungsstand unserer Wissenschaftler und damit ihre Schrittmacherfunktion für unsere geistige und unsere materielle Lebenskraft;

- die enge internationale Zusammenarbeit und Arbeitsteilung, die in der Grundlagenforschung, zumal hier, in vorbildlicher Weise geleistet wird;

- die enge Zusammenarbeit zwischen Hochschulen und Großforschungsanlagen, auf die, wie wir wissen, beide angewiesen sind;

- der Zuwachs an technischer Erfahrung, der durch die Anforderungen der Hochenergiephysik förmlich erzwungen und vielleicht stärker vorangetrieben wird, als auf allen anderen Gebieten; damit also die Zusammenarbeit von Grundlagenforschung, Technik und Industrie überhaupt in einem zentralen Bereich;

- und bei alledem schließlich die Teamarbeit, die interdisziplinäre Zusammenarbeit als solche, die wir weit über die Wissenschaft und die Grundlagenforschung hinaus in unserer Gesellschaft brauchen.

Theoretisches Wissen und technisches Können, wie es hier von vielen Mitarbeitern aller Sparten gefördert wird, hat einen wesentlichen Einfluß darauf, welchen Platz unser Land einnimmt und welchen Beitrag wir zur Lösung der Probleme der Welt leisten können. Dafür gilt es, heute allen Mitarbeitern von DESY und allen Beratern und Freunden in der Welt

This occasion and the whole anniversary will provide new information for the public on results obtained at DESY and from basic research in general. The obligation to give reasons for basic research, the effort to make it understandable to the public is necessary and wholesome. No one wants to free those responsible scientists from this obligation. But I think the scientists themselves would not want this either. They will insist on making this effort themselves. In addition to the heart of the research here into the fundamental principles and symmetries of nature, there are other significant features in the foreground when we think of DESY and celebrate its 25th birthday:

- the broadening of training with which high energy physics benefits the education of all our scientists and with it gives impulses to our spiritual and material vitality;

- the close international cooperation and division of labour which is demonstrated beautifully here in basic research;

- the close cooperation between national research centres and universities on which both are dependent, as we all know;

- the expansion of technical experience, brought by the demands of high energy physics and perhaps even more forcefully required here than in any other area; included in this is the cooperation between basic research, technology and industry in one central area;

- last but not least, the teamwork and the interdisciplinary cooperation which our society needs not only in science and basic research.

Theoretical knowledge and technical ability which is demanded from many colleagues here from many branches, has a significant influence on the position our country holds and what contribution we are able to make to solving the problems in the world. Therefore we must thank all the staff at DESY, all the advisors and

aufrichtig zu danken. Möge DESY mit DORIS, PETRA und später HERA eine erfolgreiche Zukunft beschieden sein - eine Zukunft, die uns mit tieferer Einsicht und größerem Können unsere gemeinsame Verantwortung für die Erde begreifen läßt, die wir bewohnen und die wir unbeschädigt einer nachfolgenden Generation übergeben wollen.

friends throughout the world. Let us hope that DESY together with DORIS, PETRA and, in the next few years, HERA be granted a successful future - one that allows us with deeper understanding and increased ability to comprehend our common responsibility for the earth on which we live and which we want to leave undamaged for the next generation.

Foto DESY Jürgen Schmidt (37898/33)

Grußansprache von

Dr. Klaus von Dohnanyi
Erster Bürgermeister der Stadt Hamburg

Herr Bundespräsident,
Herr Prof. Soergel,
Herr Präsident der Bürgerschaft,
meine sehr verehrten Damen und Herren!

Ich möchte Ihnen im Namen des Senats der Freien und Hansestadt Hamburg herzliche Glückwünsche zu diesem 25. Geburtstag überbringen. Und ich möchte bei der Gelegenheit noch einmal unsere ganz besondere Freude darüber ausdrücken, daß Sie, Herr Bundespräsident, in einem Zeitraum von vierzehn Tagen zum zweiten Mal nach Hamburg gekommen sind. Früher, in kaiserlichen Zeiten, wäre es sehr wohl möglich gewesen, daß die Stadt ihre Tore zugehalten und gesagt hätte, der soll mal ein paar Stunden warten. Aber wir haben Sie wirklich herzlich erwartet, Herr Bundespräsident. Es war der Nebel. Das Hamburger Wetter ist, wie ich Ihnen bei Ihrem letzten Besuch nachgewiesen habe und auch heute gegen Mittag wieder nachweisen kann, sehr viel besser als sein Ruf, aber gegen den Nebel konnten natürlich auch die vielen DESY-Schilder in der Stadt nichts tun.

Ich begrüße Sie, Herr Botschafter Ferraris, sehr herzlich hier unter uns und unterstreiche, daß unsere Beziehungen zu Ihrem Land unverändert die sind, die wir immer gehabt haben.

Ich freue mich auch, daß frühere Kollegen von mir unter uns sind. Insbesondere möchte ich herzlich den Kollegen Rembser aus dem Bundesministerium für Forschung begrüßen, mit dem ich viele Jahre zusammengearbeitet habe und der hier heute die Worte für den Bundesminister spricht. Grüßen Sie den Herrn Bundesminister aus Hamburg. Wir freuen uns immer, wenn die Beziehungen zwischen Ihnen und uns fruchtbar sind.

Ich möchte auch ganz herzlich Herrn Professor Panofsky begrüßen. Herr Profes-

Address from

Dr. Klaus von Dohnanyi
First Mayor of Hamburg

Herr Bundespräsident,
Prof. Soergel,
Herr Präsident der Bürgerschaft,
Ladies and Gentlemen!

On behalf of the senate of the Freien und Hansestadt Hamburg I would like to congratulate you on the occasion of your 25th birthday. I would also like to take the opportunity to thank you, Herr Bundespräsident, for visiting Hamburg for the second time in fourteen days. In earlier imperial days it would have been possible that the city would have closed its doors and said you should wait for a few hours. However, we have sincerely looked forward to seeing you Herr Bundespräsident. It was the fog. Hamburg weather is, as proven to you last time and this time around noon, much better than its reputation. However, even the many DESY signs around the town could do nothing against the fog.

I welcome you Ambassador Ferraris, to us here and underline that our relations with your country are the same as they always have been.

I am also pleased that former colleagues of mine are here today. In particular I would like to welcome colleague Rembser from the research ministry, with whom I worked for many years and who will talk on behalf of the minister today. Best regards from Hamburg to the minister in Bonn. We are always very happy when the relations between you and us are fruitful.

I would also like to welcome sincerely Professor Panofsky. Professor Panofsky, you are one of the great names in physics, but the name of your family also counts a great deal in Hamburg, and therefore I especially appreciate that you have come from the U.S.A. to DESY.

Ladies and gentlemen, there is nothing that has occupied man more than the question how did the world begin, what is

sor Panofsky, Sie haben sich selbst einen großen Namen in der Physik gemacht; aber auch der Name Ihrer Familie zählt sehr viel in Hamburg, und ich begrüße es deshalb ganz besonders, daß Sie aus den Vereinigten Staaten zu uns gekommen sind.

Meine Damen und Herren, nichts hat die Menschen so beschäftigt wie die Frage nach dem Entstehen der Welt; was ist Materie, woraus ist die Welt gemacht? Und auch in einer Zeit, in der die Wissenschaftsskepsis offenkundig zunimmt, müssen wir, und der Bundespräsident hat das eben unterstrichen, die Notwendigkeit der Grundlagenforschung als ein elementares Element des menschlichen Seins unterstreichen. Ich weiß, welche Debatten um Großbeschleuniger oder ähnliche Einrichtungen ausgelöst werden können. Einige sind hier unter uns, die noch wissen, wie Anfang der siebziger, Ende der sechziger Jahre die Debatte um Stanford lief und um die Konkurrenz mit CERN. Das alles hat uns damals sehr beschäftigt. Ich werde nie vergessen, mit wieviel skeptischen Worten, das sage ich hier einmal offen, mein damaliger Berater und ich will sagen, fast Freund, Werner Heisenberg, dem damaligen Ansinnen neuer Großunternehmen entgegenstand.

Trotzdem ist das, was Sie hier tun und was Sie mit einem nächsten Schritt mit HERA ja noch weiter vertiefen wollen und können, so hoffe ich, ein ganz entscheidender Beitrag zum Wissen über unsere Welt. Mir scheint, es ist kein Argument, allein auf wirtschaftliche Möglichkeiten hinzuweisen. Wir dürfen ja auf die Dauer nicht in die Lage kommen, daß wir in der Bundesrepublik nur noch etwas tun, weil wir fürchten, wenn wir es nicht tun, tun es die Japaner; und die fürchten ihrerseits, wenn sie es nicht tun, tun es die Deutschen.

Diese Art von Argumentation müssen wir verlassen, und dennoch müssen wir wissen, daß es natürlich auch einen wirtschaftlichen Bezug gibt. Aber dieser ist nicht das Hauptargument, auch nicht hier an dieser Stelle, wenn man auf die letzten

Foto DESY Jurgen Schmidt (57899/0)

matter and what is the world made of? Also in times when scepticism about science is on the increase we must, and the Bundespräsident has just emphasized this, underline the necessity of fundamental research as a basic element of human life. I know the sorts of debates that are provoked by accelerators and other similar installations. There are some of you who remember the discussions at the end of the sixties and beginning of the seventies about Stanford and the competition with CERN. That occupied us a great deal at that time. I will never forget the sceptical words with which, I say openly, my advisor at that time and I want to say almost friend, Werner Heisenberg, greeted the plans for the new large scale projects.

Despite that, what you do here and what you, with the next step, want to further develop with HERA can, I hope, make a decisive contribution to our knowledge of our world. It appears to me that it is no argument just to point at

25 Jahre und auf die nächsten 25 Jahre schaut. Es gibt einen alten Satz, der heißt: "Irren ist menschlich". Ich meine, man sollte eigentlich sagen: "Wissen ist menschlich". Was den Menschen vom Tier unterscheidet, die Suche nach Erkenntnis, das Wissen und Grundlagenforschung, ist der Kern dieses Versuchs, dieses Suchens nach Wissen.

Sicherlich, Herr Bundespräsident, Sie haben eben auch darauf hingewiesen, müssen wir Prioritäten setzen. Überall da, wo wir mit öffentlichen Mitteln Forschung fördern, treffen wir auch Entscheidungen über Forschungsrichtungen. Die Frage nach der Freiheit von Forschung und Lehre ist immer auch eine Frage nach der Anwendung von Mitteln, und jeder, der Haushalte macht, muß das wissen. Und ich sage Ihnen, ich habe seit neun Minuten die Haushaltsberatungen des Senats laufen, deswegen möchte ich Sie auch bitten, daß Sie mich nach meiner Rede freundlich entlassen. Jede Minute kann dort viel Geld kosten, und ich möchte das Geld gerne in die richtige Richtung bringen.

Dabei will ich hier einen Grundsatz sagen, meine Damen und Herren, Hamburg ist eine Stadt von nur 1,6 Millionen Einwohnern, nach West-Berlin die größte in der Bundesrepublik, aber ein Stadtstaat mit engen Grenzen. Die einzige Weise, wie wir unsere Position auf die Dauer hier halten können, ist, daß wir unsere begrenzten Mittel auf die für die Stadt und für die Bürger wirklich wichtigen Fragen konzentrieren und daß wir dann dort, wo wir arbeiten, Qualität zum ersten Maßstab machen. Es sollte nichts Mittelmäßiges geben. Lieber weniger an einer Stelle, dafür aber das Richtige. Der Qualitätsmaßstab wird auch zählen, wenn wir im Bereich von Forschung und Wissenschaft in Hamburg den Versuch machen, die immer zu knappen Mittel zu verteilen. Denn was im Freistaat Bayern der Steuerzahler in Passau auch leistet für die Kultur in München, das müssen die Hamburger Bürgerinnen und Bürger sich selbst erwirtschaften und sich auch selbst bezahlen.

the economic possibilities. We cannot in the long run come to the point where we only do something, because we fear that if we don't do it the Japanese will and they fear that if they don't do it the Germans will.

We must forget this sort of argument, but we must also know that there are, of course, economic aspects. However, this is not the main argument, particularly when one looks from here over the past and future 25 years. There's an old saying that goes: "Error is human." I think one should really say: "Knowledge is human." The thing that separates man from animals is the search for understanding. Knowledge and fundamental research are the core of this effort, of this search for understanding.

We must of course, as you have just indicated Herr Bundespräsident, set priorities. Everywhere where research is financed by public money we have to decide on the direction of the research. The question of freedom of research and teaching is always a question of the application of means and everyone who plans a budget should know that. I should mention that the budget planning in the senate started nine minutes ago and therefore I ask that you permit me to leave at the end of my speech. Every minute can cost a lot of money there and I would like to direct the money in the right direction.

I would like to mention a principle here, ladies and gentlemen. Hamburg is a city with only 1.6 million inhabitants, the largest in the Federal Republic of Germany after West Berlin; but it is a city-state with tight boundaries. The only way in which we can maintain our position here in the long run is to concentrate our limited means on those questions which are important for the city and for its citizens. We must make quality the first measure of where we work. There should be no mediocrity. Rather a little less on one place, but then in the right one. This measure of quality will also apply when we try to divide the always too limited means in the area of research and science. What

Ich möchte am Ende noch einmal meine herzlichen Glückwünsche aussprechen und den Mitarbeiterinnen und Mitarbeitern danken für das, was hier für die Wissenschaft in der Welt, für die Wissenschaft in der Bundesrepublik und in unserer Stadt geleistet wird.

Ich habe ein kleines Gastgeschenk mitgebracht, Herr Professor Soergel, das ich Ihnen gerne übergeben würde. Es ist ein englischer Kupferstich aus dem Jahre 1791, der den Titel "Magnetism" trägt. Es sind zwar keine Supraleiter, die hier vorgestellt sind, meine Damen und Herren, aber es sind doch Dinge, die gewissermaßen der Geschichte der Wissenschaft die Wege vorgezeichnet haben, auf denen Sie heute hier so erfolgreich gehen. Noch einmal herzlichen Glückwunsch und alles Gute für DESY und Ihre Arbeit.

the free state of Bavaria affords for culture in Munich is also paid for by the taxpayer in Passau; however, the citizens of Hamburg must earn that for themselves and pay for it themselves.

To finish I would like to heartily congratulate you all again and to thank the employees here for what they achieved for science in the world, in the Federal Republic and in our city.

I have brought a small present with me, Professor Soergel, which I would like to give to you. It is an English copper engraving from the year 1791 with the title "magnetism". It is not a superconductor, which is presented here, ladies and gentlemen, but there are particular things that have guided the history of science, and which you have so successfully followed here. Once again congratulations and best wishes for DESY and its work.

Foto DESY-PR Florian Becker

Grußadresse von

Dr. Josef Rembser
Vorsitzender des DESY-Verwaltungsrates

Sehr verehrter Herr Bundespräsident,
sehr geehrter Herr Bürgermeister,
lieber Professor Soergel,
meine sehr geehrten Damen und Herren!

Für die Bundesregierung in Bonn, besonders aber im Auftrag von Bundesforschungsminister Dr. Riesenhuber, überbringe ich herzliche Grüße und Wünsche zur 25-Jahrfeier. Das gesamte Bundesforschungsministerium schließt sich an.

Die Grüße und Wünsche gelten allen, die für DESY in dem Vierteljahrhundert seit 1959 an zahllosen Orten und Plätzen geplant, gearbeitet und sich eingesetzt haben, die in wissenschaftliche Forschungen, in neue Techniken, in die Experimente und Anlagen des Laboratoriums ihre Hoffnungen und ihr Engagement einbrachten, deren Erwartungen und Träume sich vielleicht nicht immer erfüllten, in der Bilanz der Ergebnisse aber die reiche Frucht neuen Wissens und technischen Könnens brachten.

"DESY ist", so sagte Bundesforschungsminister Riesenhuber bei der kürzlichen Unterzeichnung des Finanzabkommens zwischen der Freien und Hansestadt Hamburg und dem Bund für die neue Speicherringanlage HERA am 6. April dieses Jahres in der großen Experimentierhalle zwischen dem Crystal Ball- und dem ARGUS-Experiment, "DESY ist für unser Land als naturwissenschaftliche Nation eines der Flaggschiffe, die sich auszeichnen durch Exzellenz, aber auch ... durch eine hervorragende Technik, durch eine solide Hardware, durch vernünftige, ingenieurmäßige Kenntnis ... (DESY und mit ihm) HERA werden in diesem Jahrzehnt eines der ganz großen Experimente der Grundlagenforschung in Deutschland sein".

Ein Flaggschiff, meine sehr verehrten Damen und Herren, ist der Ort der Führung eines Verbandes von Schiffen, bildlich etwa bestehend aus unseren Großforschungszentren außerhalb der Universi-

Greeting from

Dr. Josef Rembser
Chairman of the DESY Administration Board

The Honorable Herr Bundespräsident,
The Honorable Herr Bürgermeister,
Herr Soergel,
Ladies and Gentlemen!

On behalf of the Federal government in Bonn and in particular the Minister of Research Dr. Riesenhuber, I bring greetings and congratulations for the 25th anniversary celebrations. The whole of the Research Ministry is also included in these wishes.

The greetings are for all who have planned, worked and made efforts for DESY at countless places in the 25 years since 1959, and for all who brought hopes and commitment to scientific research, new technology, experiments and machines in the laboratory. It's possible that their expectations and dreams did not always come true, but overall their results brought a plentiful fruit of new knowledge and technical know-how.

As the Minister of Research, Dr. Riesenhuber, said at the recent signing of the financial contract between the Freien und Hansestadt Hamburg and the State for the building of HERA on April 6th this year, held in the large experimental hall between the Crystal Ball and the ARGUS experiments: "DESY is one of the flagships of our country as a scientific nation, which is noted by its excellence, but also ... with its excellent technology and solid hardware, its sensible engineering knowledge ... (DESY and with it) HERA will be one of the important basic research experiments in Germany in this decade."

A flagship, ladies and gentlemen, is the place for the control of a formation of ships. In a figurative sense it consists of the national research centres outside the universites. DESY also is a flagship of a formation of research collaborations and basic research insti-

täten. DESY ist aber auch Flaggschiff einer Flottille aus Forschungsteams und Forschungsinstituten der Grundlagenforschung und Hochenergiephysik aus vielen Nationen, die wissenschaftliches Neuland ansteuern, und bei denen jeder im hohen Topmast seines Schiffes im friedlichen Wettstreit mit den Kollegen nach den ersten Anzeichen und nach den Gewißheiten neuer Ufer Ausschau hält.

DESY ist von Anfang an ein Ort der Zusammenarbeit zwischen Wissenschaftlern und Ingenieuren aus vielen Ländern der Welt gewesen.

Es hat bei seinem Aufbau in den 60er Jahren aus den Erfahrungen der Beschleunigertechnik und Hochenergiephysik in den USA gelernt. Mit den Fachkollegen und Schwesterlaboratorien der europäischen Staaten bestehen über die 25 Jahre Geschichte hinweg, die wir feiern, freundschaftliche und wertvolle Kontakte. Das europäische Hochenergiephysik-Laboratorium CERN in Genf, vergangene Woche 30 Jahre alt geworden, war Vorbild und Helfer, ist seit langem aber schon Sparringspartner und friedlicher Konkurrent zugleich.

Wir sind stolz, daß DESY offen ist für jedes qualifizierte Experiment, für jede Wissenschaftlergruppe - ohne Ansehen der Herkunft, ausgewiesen durch die Qualität ihrer Erfahrungen, die Kreativität ihrer Ideen, die Originalität und Zielsetzung ihrer Experimentiervorschläge. Dies sind allein die "Eintritts-Tickets", die gefordert werden.

Wir wissen zu schätzen, daß das Angebot, bei DESY zu experimentieren und über die Ergebnisse nachzudenken, von vielen ausländischen Freunden angenommen worden ist und in wachsendem Maße weiter angenommen wird. Wir sind besonders dankbar, daß Laboratorien und Regierungen aus anderen Ländern mit Personal und wertvollen Komponenten zum Bau der neuen Speicherringanlage HERA beitragen. Dieses Engagement unserer ausländischen Freunde war mit entscheidend für den Baubeschluß.

Wer in die Labors, in die Werkstätten, in die Computer- und Kontrollräume, in

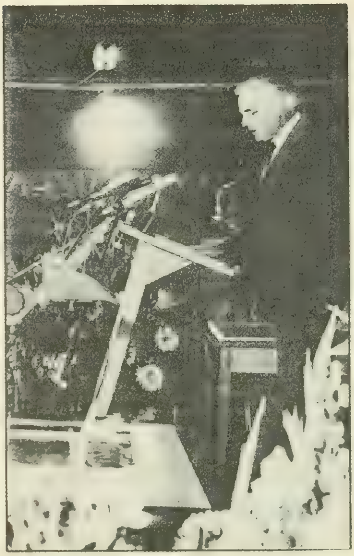


Foto DESY Jurgen Schmidt (37899/1)

tutes for high energy physics around the world, which select the course of scientific new land. In peaceful competition with his colleagues, he looks out for the first signs and proof of new shores from the top of the mast of his ship.

Since the beginning DESY has been a place of cooperation between scientists and engineers from many countries.

During its build up in the sixties a lot was learnt on accelerator technology and high energy physics from the U.S.A. For longer than the 25 years which we are celebrating today, we have also had friendly and fruitful contacts with experts and our sister laboratories in Europe. The European high energy physics laboratory, CERN in Geneva, which had its 30th birthday last week, was an example and helper, and has long been a sparring partner and friendly competitor.

We are proud that DESY is open for every qualified experiment and scientific

die Experimentierhallen von DESY und seine Abteilungen für die einzelnen Experimente hineinschaut, wird beeindruckt sein von dem Untereinander-Verstehen, von der gemeinsamen Arbeit und auch von den Freundschaften, die dort zwischen vielen in der Wissenschaft begeisterten jungen Menschen unterschiedlicher Sprache wachsen. Dies sind die wichtigsten Investitionen der Vergangenheit und der Zukunft hier in Hamburg-Bahrenfeld.

DESYaner zu sein, kommt dem Besitz eines "internationalen Forscherausweises" gleich, über dessen Einführung gerade heute vor einer Woche die Forschungsminister der Mitgliedstaaten des EUROPARATES in Paris berieten. Die Zahl der internationalen Einladungen für DESYaner, über die Resultate der Hochenergie- und Synchrotronstrahlungs-Experimente an DORIS und PETRA zu berichten, Rat und Expertise zur Verfügung zu stellen, ist Legion. Mit allen Mitarbeiterinnen und Mitarbeitern von DESY freuen wir uns heute unbeschwert über das hohe Ansehen des Laboratoriums, und wir wollen allen DESYanern - von den ehemaligen Mitgliedern des Wissenschaftlichen Rates und des Direktoriums angefangen bis hin zur gegenwärtig aktiven Mannschaft - für ihre Arbeit und ihre Beiträge danken.

Die Bundesregierung und das Bundesministerium für Forschung und Technologie werden auch künftig dem Deutschen Elektronen-Synchrotron DESY ihre Sympathie und ihre Förderung geben.

Foto DESY Jürgen Schmidt (37899/15)

team, whatever their origin, depending only on the quality of their knowledge, the creativity of their ideas and the originality and aims of their experimental proposals. These are the "entrance tickets" required here.

We are well aware that the offer from DESY on experimentation and reflection on the results of experiments has been taken up by an increasing number of foreign friends. We are particularly grateful that laboratories and governments from other countries will contribute experts and components for the building of the HERA storage rings. This commitment from our foreign friends was an important point in the decision to build HERA.

If you take a look into the various laboratories and workshops, the computer and control rooms, in the experimental halls and the sections for each experiment, you will always be impressed by the understanding, the team work and the friendships of the many young science enthusiasts with different languages which grow there. These are the most important investments in Hamburg-Bahrenfeld both for the past and for the future.

To be a member of the DESY staff is the same as to own an "international research identity card". By the way, the research ministers of the member states of the Council of Europe conferred about such an identity card in Paris just one week ago. There are a great number of international invitations to DESYaner to talk about the results of high energy and synchrotron radiation experiments at DORIS and PETRA, and to make available expertise and advice. All the workers at DESY enjoy the respect in which DESY is held tremendously and we would like to thank all DESYaner - beginning with the earlier members of the Scientific Council and the directorate and including the present staff - for their work and contributions.

The Federal government and the Ministry for Research and Technology will in future continue to demonstrate their sympathy and support for DESY.

Grußadresse von

Prof. Joachim Treusch
Präsident der Dt. Physikal. Gesellschaft

Verehrter Herr Bundespräsident,
liebe DESYaner,
verehrte Gäste!

DESY steht im Mittelpunkt des Interesses, zum dritten Mal in diesem Jahr: die Unterzeichnung eines Vertrages im April, der Abdruck eines Artikels im Spiegel, die Feier des Geburtstags im September; was ist zu sagen?

Nun, es ist seit je ein Problem gewesen für die Physiker, im öffentlichen Ansehen die Rollen von Faust und Mephisto gleichzeitig zu spielen. Man sieht sie allein verantwortlich für Transistor und Bombe, fixiert auf das enge Verständnis des Denk- und Machbaren, selbst da noch begrenzt.

Die Frage "Grundlagenforschung - Fluch oder Segen?" ist gestellt und muß beantwortet werden. Ich kann und will Herrn Panofsky nicht vorgreifen, eines aber scheint mir sicher: Der publizistische Tanz eines Londoner Studenten um den vermeintlichen Tod einer Königin birgt keine Antwort. Zudem kann jeder sehen, daß sich DESY und die Damen ihres Hofstaats, allen voran DORIS und PETRA, bester Gesundheit erfreuen.

Was über diesen Augenschein hinaus bewegt die Physiker und insbesondere die Deutsche Physikalische Gesellschaft, hier und heute Dank zu sagen, DESY öffentlich Glück zu wünschen.

Ich will nicht von "Charm", "Tau" und "Ypsilon" reden, das werden Berufenere tun. HASYLABs Erfolge zu rühmen, von denen ich mehr verstehe, fehlt mir die Zeit, nicht der Wille. Lassen Sie mich ein paar allgemeinere Begründungen geben.

Bei DESY scheint mir - im Gegensatz zum Fall der bemannten Raumstation -

Greeting from

Prof. Joachim Treusch
President of the German Physical Society

Herr Bundespräsident,
DESYaner,
Hounered Guests!

DESY is at the centre of interest for the third time this year: the signing of the HERA contract in April, an inconsiderate article in "Der Spiegel" in August, and its birthday celebrations in September. What should one say about it all?

It has always been a problem for physicists to simultaneously play the roles of Faust and Mephisto in public. They are seen as being responsible for the transistor and for the bomb, fixed on the understanding of the imaginable and the possible and even there very specialised.

The question "Basic Research - Curse or Blessing?" has been put and must be answered. I cannot and do not want to anticipate Wolfgang Panofsky, but one thing appears to me to be certain: The public dance of a London student over the supposed "Death of a Queen" does not contain an answer. Everyone can see that DESY and the ladies of her household, in particular DORIS and PETRA, are in the best of health.

This over and above just the appearance, moves the physicists and especially the German Physical Society, to thank and publicly congratulate DESY. I don't want to talk on "charm", "taus" or "upsilons". There are other, more qualified, people here for that. Praising HASYLAB's successes, which I understand more about, would be more appropriate, but I lack the time. Let me give a few general reasons.

It appears to me that at DESY - in contrast to the manned space station - it is proved that the scientific uses are in good proportion to the effort made. We feel the effect of this large scale research institute working at the boundaries of knowledge in the scientific trai-

erwiesen, daß der wissenschaftliche Nutzen in gutem Verhältnis zum Aufwand steht:

Wir spüren die Ausstrahlung dieser an den Grenzen der Erkenntnis arbeitenden Großforschungsanlage für den wissenschaftlichen Nachwuchs. Wir erleben, daß Hamburg zum Anziehungspunkt für die internationale Fachwelt wird. Wir wissen, daß die Zusammenarbeit DESYs mit den Universitäten - nicht nur gefordert, sondern hier zum Wohle beider immer gefördert - der wesentliche Antrieb für 25 Jahre lebendiger, erfolgreicher Forschung war und weiter sein wird. Wir sind überzeugt, daß diese Forschung mit ihren Ergebnissen auch für das Selbstverständnis einer Kulturnation ihren Preis wert ist.

Spuren sind gefunden worden, Spuren werden bleiben im sich ändernden Bild der Welt, zu der wir gehören. Dafür danken wir, dazu beglückwünschen wir die Mitarbeiter von DESY, dazu gratuliere ich Ihnen, lieber Herr Soergel.

Im Namen der Deutschen Physikalischen Gesellschaft wünsche ich DESY für seine reiferen Jahre Weisheit bei der Planung und Partnerwahl, Kraft bei der Durchführung ihrer Forschungsaufgaben und Erfolg bei der weiteren Suche nach Erkenntnis.

Foto DESY Jurgen Schmidt (37898/32)

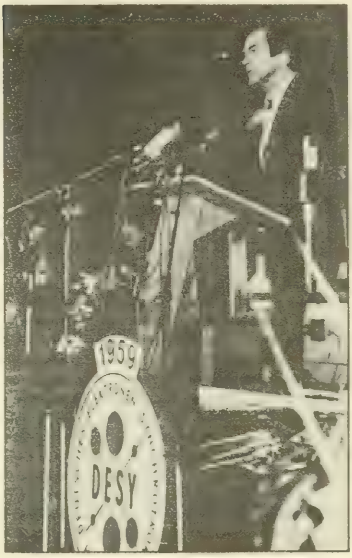


Foto DESY Jurgen Schmidt (37899/5)

nees. We see that Hamburg has become a centre of attraction for international experts. We know that the cooperation of DESY with the universities - not only demanded, but also improved to the benefit of both sides - was a significant force in 25 years of lively and successful research and will continue to be so. We are convinced that this research together with its results is worth its price, also for the conception of a culture nation.

Tracks have been found, tracks will remain in our changing picture of the world to which we belong. Therefore we thank you DESYaner and congratulate you Herr Soergel.

In the name of the German Physical Society I wish DESY for the next years wisdom in its planning and choosing of partners, strength in the execution of its research tasks and success in the further search for knowledge.

Grußadresse von

Dr. Peter Fischer-Appelt
Präsident der Universität Hamburg

Sehr verehrter Herr Bundespräsident,
Herr Präsident der Bürgerschaft,
lieber Herr Soergel,
meine Damen und Herren!

"Das Deutsche Elektronen-Synchrotron in Hamburg-Bahrenfeld ist ohne Zweifel als ein Glanzpunkt der Hamburger Physik zu bezeichnen". Das schrieb 1969 kein Geringerer als Pascual Jordan. Heute, 15 Jahre später, ist dieses Urteil weit über Hamburg hinaus auf die ganze Bundesrepublik auszudehnen.

Ich freue mich ganz besonders, daß ich heute stellvertretend für alle Mitglieder der Hamburger Universität zusammen mit Ihnen, meine Damen und Herren, die Sie bei DESY arbeiten, das 25jährige Jubiläum Ihres großartigen wissenschaftlichen Unternehmens begehen kann. Ich überbringe Ihnen im Zeichen tiefer Verbundenheit die Grüße und die besten Wünsche der Universität Hamburg zu diesem Jubiläum.

DESY, meine Damen und Herren, würde es vielleicht nicht hier in Hamburg geben, wenn es in Hamburg nicht zuvor eine bedeutende Tradition physikalischer Forschung gegeben hätte. Aus ihr sind mehrere Nobelpreisträger hervorgegangen, die in den zwanziger Jahren in der damals noch jungen hamburgischen Universität gewirkt haben. Otto Stern, der 1943 den Nobelpreis für Physik erhielt, hatte bereits vor seiner Berufung nach Hamburg auf den Lehrstuhl für physikalische Chemie im Jahre 1923 die für die Quantenphysik bahnbrechende Entdeckung des Stern-Gerlach-Effektes gemacht. Er, wie viele andere Mitglieder unserer Hochschule, mußte 1933 Land und Universität verlassen. Ihrer zu gedenken, ist heute eine besondere Pflicht und ein tiefes Anliegen des Herzens.

Ein anderer, der hier zu nennen ist, war Wolfgang Pauli, das sprichwörtliche Gewissen der deutschen Physik in der Zeit des größten Aufbruches in diesem Jahrhun-

Greeting from

Dr. Peter Fischer-Appelt
President of the University of Hamburg

Herr Bundespräsident,
President of the Bürgerschaft,
Herr Soergel,
Ladies and Gentlemen!

"The German Electron Synchrotron in Hamburg-Bahrenfeld is, without dout, one of the high points of physics in Hamburg". That was written in 1969 by no less a person than Pascual Jordan. Today, 15 years later, this judgement has to be extended throughout the whole of the Federal Republic.

I am particularly pleased that I, on behalf of all members of the University of Hamburg, can take part in the 25th anniversary of this great scientific institute together with you, ladies and gentlemen who work at DESY. I convey to you, as a sign of our deep collaboration, greetings and best wishes from the University of Hamburg for this anniversary.

It is possible, ladies and gentlemen, that DESY would not exist in Hamburg, if there hadn't already been a tradition of physics research here. It goes back to several Nobel prize winners, who worked here in the twenties in the newly founded university. Otto Stern, who received the Nobel prize for physics in 1943, had made the pioneering discovery for quantum physics of the Stern-Gerlach effect before his appointment as Professor of physical chemistry in Hamburg in 1923. He, in common with many others from our university, had to leave the country and university in 1933 and it is with a special responsibility and a heartfelt wish that we remember them.

Another, who should be named here, is Wolfgang Pauli, the proverbial conscience of German physics during the time of greatest uprise in this country. He discovered the famous equivalence theorem on the Rothenbaumchaussee and received the Nobel prize for it later. Isaac Isidor Rabi and Hans Jensen, also Nobel prize winners, have come from their

dert, der auf der Rothenbaumchaussee das berühmte Äquivalenz-Verbot entdeckte und später den Nobelpreis dafür erhielt. Isaac Isidor Rabi und Hans Jensen, zwei weitere Laureaten, sind aus ihrer Schule hervorgegangen. Es ist, meine ich, keine geringe Sache, daß eine junge Universität in einem so wesentlichen Forschungsgebiet unseres Jahrhunderts wie der Physik so früh bahnbrechende Entdeckungen aufzuweisen hat, und deswegen, meine Damen und Herren, ist es sicher auch der Genius loci gewesen, der in dem neuen Anlauf, die alten Erkenntnisse der theoretischen Physik experimentell zu verifizieren, in Hamburg zum Zuge gekommen ist.

DESY ist heute eine internationale Einrichtung. Seine Direktoren Jentschke, Paul, Schopper und Soergel, von denen drei Professoren der Hamburger Universität sind, haben mit ihren Mitarbeitern ganz wesentlich dazu beigetragen, daß der ausländische Vorsprung in der Elementarteilchenphysik in den letzten 25 Jahren eingeholt worden ist und die deutsche und europäische Teilchenphysik wieder Weltgeltung zurückgewonnen hat.

Diese Erfolge sind auch auf eine nahezu symbiotische Zusammenarbeit zweier auf diesem Gelände gelegener Institute der Hamburger Universität mit DESY zurückzuführen, vor allem aber auf Weitblick, Wagemut und Kooperation und den spezifischen Charme der Wegbereiter dieses Unternehmens, die heute zu unserer Freude alle unter uns sind. Ein Charme, der uns nie hat vergessen lassen, daß die gigantischen Anlagen, die hier errichtet worden sind und noch werden, den Blick nicht verstellen gegenüber der Menschlichkeit des forschenden Geistes, der hier am Werke ist. Möge zu der bewundernswürdigen Anstrengung des Fragens das Quäntchen Glück hinzutreten, das richtige Antworten gewährt, und möge im Umgang mit solchen langersehnten Antworten und neugestellten Fragen die Besonnenheit erhalten bleiben, die uns, zumal an den letzten Grenzen der Erkenntnis, vonnöten ist.

Ich entbiete Ihnen allen den herzlichen Glückwunsch der Hamburger Universität.

Foto DESY Jürgen Schmidt (37899/6)

school. It is perhaps no small thing that such a young university has made such pioneering discoveries in an important field like physics. Therefore ladies and gentlemen, it was certainly the genius loci that in the new beginning Hamburg was one of the places where the old knowledge from theoretical physics was experimentally verified.

Today DESY is an international institute, and its directors Jentschke, Paul, Schopper and Soergel, three of which are professors at the Hamburg university, and its staff have significantly contributed to the fact that the foreign lead in elementary particle physics has been caught up and German and European particle physics has won back international recognition over the past 25 years.

These successes can be traced back to an almost symbiotic cooperation between the two institutes from the University of Hamburg and DESY, and most importantly to the vision, daring, cooperation and specific charm of the pioneers of this undertaking, who are happily all here today. This charm has never let us forget human side of research here, despite the huge instruments which have been and will be built. Let's hope that the admirable questioning drive receives its necessary quantum of luck to find the right answers, and let's hope that in dealing with these long searched for answers the thoughtfulness is retained, which is necessary at the limits of our knowledge.

I bring you all the heartiest congratulations from the University of Hamburg.

"Grundlagenforschung - Fluch oder Segen?"

Festvortrag von
Prof. Wolfgang K. H. Panofsky

Sehr geehrter Herr Bundespräsident,
lieber Herr Soergel,
liebe Freunde und Kollegen!

Wir haben uns hier versammelt, um das 25jährige Jubiläum von DESY zu feiern. Es freut mich sehr, daß ich an diesem Fest mitwirken kann, und zwar aus mehreren Gründen. Erstens ist DESY ein Schwesterinstitut des Stanford Linear Accelerator Center, kurz SLAC, das zur Stanford-Universität in Kalifornien gehört und wo ich seit 34 Jahren arbeite. SLAC und DESY arbeiten auf ähnlichen Gebieten, wir betreiben beide Elektronenbeschleuniger und Elektron-Positron-Speicherringe, unsere Institute haben ähnliche Größe, wir haben beide ungefähr die gleiche Zahl von Mitarbeitern und wir fangen beide jetzt an, Kollisionsmaschinen neuer Art zu bauen. Zum anderen bin ich sehr gerne hier, um DESY zu den großen Fortschritten der Wissenschaft zu gratulieren, die von hier in Bewegung gesetzt werden. Und schließlich ist dies für mich ein sentimentaler Besuch. Von 1919 bei 1934 lebte ich als Kind in Hamburg; ich wurde an der Gelehrtenschule des Johanneums erzogen, und mein Vater lehrte an der Universität Hamburg.

Die Arbeit von DESY ist Teil der weltumspannenden Unternehmung, die zum Ziel hat, die Geheimnisse der Natur zu enthüllen. Sie wissen alle, daß seit der Zeit der alten Griechen der Mensch wissen wollte, aus welchen Bausteinen seine Welt konstruiert sei. Der kleinste Teil der Materie der selbst noch "derselbe" ist, wurde von den Griechen "atomos" d.h. "unteilbar" genannt. Inzwischen wissen wir, daß das Atom nicht unteilbar ist. Wir wissen, daß es einen Durchmesser von ungefähr 10^{-8} cm hat; das bedeutet, daß ein Schnitt durch das menschliche Haar etwa eine Million Atome durchquert. Heute sind die Physiker zu dem ziemlich unvorstellbar kleinen Abstand von 10^{-16} cm =

"Basic Research - Curse or Blessing?"

Celebratory Lecture from
Prof. Wolfgang K. H. Panofsky

Honoured Herr Bundespräsident,
Dear Herr Soergel,
Dear Friends and Colleagues!

We are gathered here in order to celebrate the 25th Anniversary of DESY. I am particularly pleased to participate in this celebration for several reasons. First, DESY is a sister institute to the Stanford Linear Accelerator Center - SLAC for short, which is a part of Stanford University in California, which has been my place of work for the last 34 years. SLAC and DESY work on similar topics - we both operate electron accelerators and electron-positron storage rings. Our institutes are of similar size and we have about the same number of staff members. We both are now starting to build colliding beam machines using new principles.

Secondly, I am pleased to be here in order to congratulate DESY on the great progress in science which has been set in motion from here. But in addition this visit is for me a sentimental occasion. I lived in Hamburg as a child from 1919 until 1934. I was educated at the Gelehrtenschule des Johanneums and my father taught at the University of Hamburg.

DESY's work is a part of the worldwide effort whose goal is to discover the secrets of nature. We all know that since the time of the ancient Greeks it has been a human aspiration to know from which building blocks the world is constructed. The smallest part of matter which in itself is still "the same" was called by the Greeks "atom" or "indivisible". Today we know that the atom has approximately a diameter of 10^{-8} cm; this means that a cut through a human hair crosses approximately one million atoms. Today physicists have advanced to the unimaginably small distance of 10^{-16} cm = 10^{-8} x 10^{-8} cm. DESY has contributed a great deal to this progress. We can now resolve items which are smaller than the

$10^{-8} \times 10^{-8}$ cm vorgedrungen. Dies ist ein Fortschritt, zu dem DESY recht viel beigetragen hat. Sie können jetzt Dinge auflösen, die um den gleichen Faktor kleiner als ein Atom sind, um den ein Atom kleiner als ein Zentimeter ist.

Die moderne Wissenschaft dringt gleichzeitig sowohl zur "Grenze des Kleinen" als auch zur "Grenze des Großen" vor, einmal durch die Elementarteilchenphysik, zum anderen durch Kosmologie und Weltraumforschung. Es ist besonders bemerkenswert, daß sich diese Gebiete in den letzten Jahren gegenseitig stützen - um die Ereignisse im Weltall zu verstehen, braucht man die Resultate der Teilchenphysik. Beide Gebiete, Raumforschung und Teilchenphysik, brauchen große Apparaturen. Um kleine Dimensionen zu erforschen, muß man den Probeteilchen eine sehr große Energie erteilen; dies folgt aus dem Unsicherheitsprinzip von Heisenberg, nach dem eine kleine Dimension nur festgelegt werden kann, wenn man sie mit Teilchen von hoher Energie untersucht. Deshalb bezeichnen heute Hochenergiephysik und Teilchenphysik dasselbe Gebiet. In dem Maße, wie die Energie unserer Beschleuniger und Speicherringe wächst, können wir immer kleinere Dimensionen erforschen.

Aber dies ist nicht alles. Nicht nur ist die Physik der höchsten Energien und die Physik der kleinsten Teilchen dieselbe, sondern auch unsere Erforschung des Weltalls stützt sich mehr und mehr auf die Ergebnisse der Teilchphysik. Die Regeln, die die Energieerzeugung in den fernen Regionen des Kosmos bestimmen, beruhen auf Resultaten, deren Ursprung in Laboratorien wie DESY zu suchen ist. So sehen wir, daß die Teilchenphysik die Rolle des großen Vereinigers der verschiedenen Gebiete der Naturwissenschaft angenommen hat. Es ist ja nicht sehr überraschend, daß dann, wenn man die fundamentalen Bausteine der Materie und die Kräfte, die diese Bausteine zusammenhalten, etwas besser versteht, auch viele andere Gebiete der Natur verständlich werden.

Darüber hinaus ist die Teilchenphysik aber auch ein Vereiniger von Menschen.

Foto DESY Jurgen Schmidt (37899/7)

size of an atom by the same factor by which the atom is smaller than 1 centimeter.

Modern science attacks simultaneously the "limits of the small" through elementary particle physics and the "limits of the large" through cosmology and space exploration. It is particularly worth emphasizing that during the last years these two have been mutually reinforcing - in order to understand the phenomena in outer space one needs the results of particle physics. Both topics of research, space exploration and particle physics, require large apparatus. In order to explore small dimensions one must give very high energy to the particle probes; this follows from the Uncertainty Principle of Heisenberg which states that a small dimension can be determined only if it is probed with particles of very high energy. For this reason today high energy physics and particle physics designate the same topic of research. As the energy of our accelerators and storage rings grows we can explore smaller and smaller dimensions in proportion. But this is not all. Not only is the physics of the highest energies and the physics of the smallest particle the same thing, but so does the exploration of the cosmos rest more and more on the results of particle physics. The rules which determine the generation of energy in the far regions of space derive from the results which

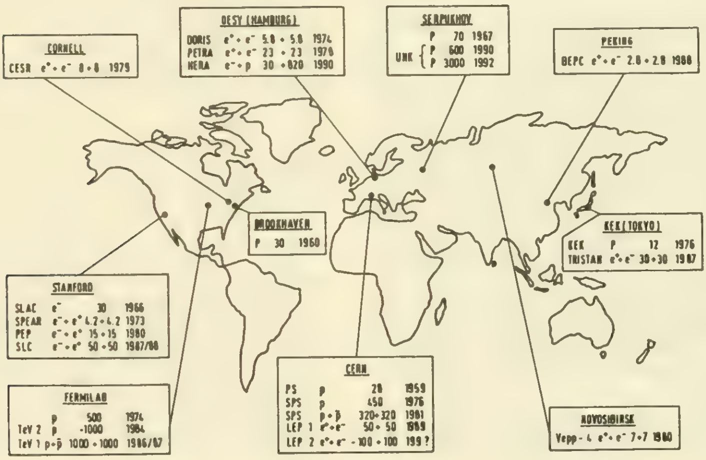
Physiker und andere Wissenschaftler, die in der ganzen Welt auf diesem Gebiet arbeiten, kennen und respektieren sich gegenseitig. Es gibt keine Geheimnisse in der Teilchenphysik. Alle neuen Resultate werden prompt publiziert. Wo sich Teilchenphysiker treffen, hört man alle Sprachen. Wissenschaftliche Vorträge werden in vielen Ländern üblicherweise in einer Sprache - Englisch - gehalten, unabhängig von der Nationalität des Sprechers oder des Ortes. Ich halte diese Rede in Deutsch, denn unsere Hörer hier sind ja nicht alle Naturwissenschaftler und Techniker! Es ist sehr wichtig, daß die Rolle der Teilchenphysik nicht nur von Spezialisten anerkannt wird, sondern daß auch allen Staatsbürgern, die das nötige Interesse aufbringen, die Gelegenheit gegeben wird, dieses Fach zu verstehen. Denn wir müssen ja alle gemeinsam für die Kosten aufkommen, die erforderlich sind, um weiterhin Teilchenphysik betreiben zu können.

have originated in laboratories such as DESY. We see, therefore, that the results of particle physics have assumed the role of the great unifier of different parts of natural science. It is not very surprising that the improved understanding of the fundamental building blocks of matter and of the forces which link these building blocks leads also to improved understanding of many other phenomena in nature.

We see that particle physics is a great unifier of different topics of science. However, particle physics is also a unifier of people. Physicists and other scientists who throughout the world work on this subject know one another and share a mutual respect. There are no secrets in particle physics. All new results are published promptly. At meetings of physicists dealing with this topic one hears all languages. Technical lectures in many countries are generally delivered in only one language - English-

Bild 1

Die Welt der Hochenergie-Beschleuniger



In beinahe allen Ländern der Welt gibt es Hochenergie-Laboratorien. Das erste Bild zeigt auf einer Weltkarte die Standorte sämtlicher Maschinen, mit denen Teilchen auf Energien von mehr als einer Milliarde Elektronenvolt beschleunigt werden können, die entweder bereits im Betrieb oder noch im Bau sind. Diese Laboratorien betreiben Anlagen verschiedener Art: Beschleuniger oder Speicherringe, Elektronen- oder Protonen-Maschinen, schwache Strahlen oder intensive Strahlen. Jede Maschine ist besonders leistungsfähig in ihrem Spezialgebiet. Die ideale Maschine für alle Zwecke ist noch nicht erfunden und ist auch nicht erfindbar, eine "beste Maschine der Welt" für die Teilchenphysik gibt es nicht. Ich betone dies, um Ihnen zu veranschaulichen, daß die internationale Zusammenarbeit in diesem Gebiet nicht nur der internationalen Kultur und dem internationalen Frieden und der Verständigung dient, sondern auch rein wissenschaftlich notwendig ist.

Lassen Sie mich drei Beispiele erwähnen: Für die Untersuchung der Struktur des Protons mit höchster Auflösung wird zweifellos HERA hier in Hamburg die beste Maschine sein. Mit dem Speicherring LEP, der jetzt im CERN gebaut wird, wird es möglich sein, die so erfolgreiche Methode der Elektronen-Positronen-Kollisionen auf höchste Energien auszudehnen. Um die längst entdeckten Z0-Teilchen reichlich und verhältnismäßig billig zu erzeugen und um gleichzeitig eine neue Kollisionstechnik zu demonstrieren, ist der Stanford Linear Collider bei uns in Kalifornien die am besten geeignete Maschine.

Das Ziel der Teilchenphysik ist die Grundlagenforschung an der Materie. Aus der Geschichte wissen wir, daß die Grundlagenforschung immer zu Anwendungen geführt hat. In welchem Gebiet die Teilchenphysik Anwendung finden wird oder ob ihre Resultate überhaupt zu einer Anwendung führen, wissen wir natürlich nicht. Aber wir müssen uns daran erinnern, daß beispielsweise die Kernphysiker in den 30er Jahren auch nicht an praktische Anwendungen dachten. Der große englische Physiker Ernest Rutherford, der Entdecker

independent of the nationality of the speaker or the locale of the lecture. I am delivering this talk in German since our auditors are not all technical people! It is particularly important that the role of particle physics is not only recognized by specialists but that all citizens who share the required interest have the opportunity to understand this subject. After all, we are all paying the bill for the necessary costs to carry on work on this topic.

Laboratories which are active in this field exist in almost all countries of the world. The first figure indicates on a map of the world the location of all machines which are either in operation or still under construction which accelerate atomic particles to energies in excess of one billion electron volts (GeV). There is not such a thing as "the best machine in the world" for particle physics. These laboratories operate installations of many kinds: accelerators or storage rings, electron or proton machines, weak beams or intensive beams. Each machine is particularly effective in exploring a special topic; the ideal machine for all purposes has not been invented and is not inventable. I am emphasizing these facts in order to convince you that international collaboration in this field does not only serve international culture and international peace and understanding but is also necessary for purely scientific reasons.

I would like to give three current examples of the above. In that region of research in which one wishes to understand the structure of the proton at the highest level of detail HERA here in Hamburg will be without doubt the most effective machine. In order to extend the technique of elementary particle collisions (which has been so successful) to the highest energy the LEP storage ring in Geneva which is now being built at CERN is without question the best tool. In order to produce the recently discovered Z0 particles in large quantity and relatively cheaply and in order to demonstrate simultaneously a new technology for colliders, the SLC (Stanford

des Atomkerns, erklärte einmal: "Wer sagt, daß die Kernenergie ausgebeutet werden kann, der redet Unsinn." Aber heute haben wir Nuklearmedizin, Kernreaktoren, Kernkraftwerke - und Atombomben! Der Beitrag der Kernphysik zur Medizin ist zweifellos zum Besten der Menschheit. Ich persönlich glaube, daß dies auch für die Kernkraftwerke gilt, obgleich es darüber viel Streit gibt. Die Kernwaffen aber sind eine Last, die die Menschheit jetzt zu tragen hat. Aber trotzdem - oder vielleicht gerade wegen der Abschreckung durch die Bomben - hat es seit 39 Jahren keinen Weltkrieg gegeben - das ist viel länger als der kurze Frieden zwischen dem Ersten und dem Zweiten Weltkrieg. Schulden wir den Kernwaffen also Dank für diesen langen, aber doch irgendwie erzwungenen Frieden? Sind die Resultate der Kernphysik Fluch oder Segen? Werden die zukünftigen Resultate der Teilchenphysik von DESY und anderen Instituten der Grundlagenforschung Fluch oder Segen sein? Es gibt wenige Fragen, die wichtiger für die Zukunft der Welt sind, als diese.

Für den Staatsbürger, der sich über die Bedrohung durch die Kernwaffen oder über die Verschmutzung der Umwelt beklagt, ist es einfach, die Verantwortung auf die Wissenschaft abzuwälzen. Das ist bequem, aber falsch. Die Gesetze der Natur existieren, gleichgültig ob der Mensch sie heute, morgen oder übermorgen entdeckt. - Zum Beispiel wissen wir heute, daß der erste Kernreaktor nicht von Fermi und seinen Mitarbeitern in Chicago 1943, während des Krieges, gebaut wurde, sondern daß bereits vor zwei Milliarden Jahren eine Explosion aufgrund von Kernspaltung von der Natur in Gabun an der Westküste Afrikas ausgelöst wurde! Das wurde vor zwölf Jahren durch die Analyse des Erzes in einem Uranbergwerk entdeckt. - Der Menschheit einfach das Wissen zu versagen, ist keine Antwort auf diese schwierigen Fragen.

Die Übergänge von der reinen Grundlagenforschung zur technischen Nutzanwendung und von da zur Massenproduktion bilden eine lange Kette. Ihre Glieder sind: Experimentelle und theoretische

Linear Collider) which we are building in California is the most suitable device.

The goal of particle physics is basic research on the nature of matter. Historically we know that basic research has always led to applications. We do not know, of course, in which direction particle physics will find application, or in fact whether the results of the physics of elementary particles will find any application. But we must remind ourselves that the nuclear physicists in the 1930 decade did not think about practical applications. The great British physicist Ernest Rutherford, the discoverer of the nucleus, declared "Who says that nuclear energy can be practically used speaks moonshine." But today we have nuclear matter from nuclear reactors and nuclear power plants - and nuclear bombs! The contribution of nuclear physics to medicine is without question a boon to mankind; I believe personally that these is also the case for nuclear power plants, although this is a controversial matter. Nuclear weapons, however, are a burden which humanity now has to carry. But in spite of this, or maybe through the threat of bombs, there has not been a world war for 39 years - much longer than the short period between the first and second world wars. Do we owe thanks to nuclear weapons for this long but somehow coerced peace?

Are the results of nuclear physics a curse or a blessing? Are the future results of particle physics generated by DESY or other fundamental research institutes a curse or a blessing? There are few questions which are more important for the future of the world then these.

It is very simple for the citizen who is lamenting the threat of nuclear weapons or the degradation of the environment to place the responsibility on science. This is simple but wrong. The laws of nature exist irrespective of whether man discovers them today, tomorrow, or the day after tomorrow. For example, we know today that the first nuclear reactor was not produced by Fermi and his collaborators in Chicago during

Grundlagenforschung - Synthese von Resultaten - Erfindung einer Anwendung - Entwicklung eines Produktes - Test eines Prototypen - Auswertung - und dann endlich Produktion und Verteilung.

Nur das erste Glied dieser Kette betrifft die Entdeckung der Eigenschaften der Natur - Eigenschaften, die ohne unser Zutun sowieso existieren und ein Teil unserer Umwelt sind, egal ob wir sie erforschen und verstehen oder nicht. Die weiteren Glieder der Kette, angefangen mit einem Vorschlag zur Anwendung bis zur Produktion und Verteilung, sind unter der Kontrolle des Menschen: Wenn der Mensch ein Produkt nicht entwickelt, gibt es dieses Produkt eben nicht. Die große Frage ist deshalb: Sind die organisierten Institutionen der Menschheit und die individuelle Stärke des Einzelnen fähig, bezüglich dieses Anwendungspfads weise Entscheidungen zu treffen? Meine Überzeugung ist, daß die Menschen und ihre Institutionen im Durchschnitt bessere und sicherere Entscheidungen über die Anwendung eines Naturgesetzes treffen werden, wenn sie die Grundlagen dieses Naturgesetzes verstehen.

the war in 1943, but that a nuclear fission explosion was released by nature in Gabon on the west coast of Africa two billion years ago! This fact was discovered 12 years ago by analyzing the ore produced in a uranium mine at that location. To deny knowledge to humanity is no answer to these difficult questions.

The transition from basic science to useful technical application and finally to mass production constitutes a long chain. The links of this chain are: - experimental and theoretical basic research - synthesis of results - invention of an application - development of a product - tests on a prototype - evaluation - production and distribution.

Only the first link in this chain is dedicated to the discovery of the properties of nature - these properties exist without our participation at any account; they are a part of our environment whether we explore them or understand them or whether we do not. The further links of this chain, starting with the proposal for an application and ending with production and distribution, are

Foto DESY Jürgen Schmidt (37897/19)

Es ist sehr leicht, zu beklagen, wie gewisse Einflüsse der Technik das Leben kompliziert haben. Man muß solche Nachteile aber gegen die der Katastrophe abwägen, die sich entwickeln würde, wenn man versuchte, die existierende und zukünftige Weltbevölkerung ohne weitere technische Entwicklungen zu ernähren, zu bekleiden, ihr Wohnungen zu geben, sie zu transportieren und zu beschützen!

Die Technologie hat den Austausch von Nachrichten zwischen den Menschen aller Länder erleichtert. Ein Reseultat ist, daß Geheimnisse viel schwieriger geheim zu halten sind, sowohl im privaten wie im öffentlichen Leben. Obgleich dies im Privatleben gelegentlich recht unbequem sein mag, muß man zugeben, daß international gesehen dieser Umstand ein wichtiger Schritt zum Frieden sein kann. Die Satelliten, die jetzt die Erde umkreisen, haben viele Geheimnisschranken beseitigt. Rüstung in aller Welt zu kontrollieren, ist überhaupt nur vorstellbar, weil die Satelliten und Radaranlagen beispielsweise auch über oder durch den Eisernen Vorhang beobachten können. Das Resultat all dieser technischen Entwicklungen ist, daß wir jetzt in einer viel offeneren Welt leben als im letzten Jahrhundert.

Die Zukunft der Zivilisation ist zum großen Teil vom Fortschritt der Technologie abhängig; der wiederum hängt vom Fortschritt der Grundlagenforschung ab. Deshalb gibt es in der Welt, in der wir leben, keine Alternative zur gesellschaftlichen Pflicht, die wissenschaftliche Forschung intensiv zu betreiben. Die einzige Frage ist: Wie intensiv?

Die Grundlagenforschung kostet Geld und Arbeit. Wenn Landwirtschaft oder Industrie in Schwierigkeiten sind, hört man oft die Frage: "Ja können wir uns die Grundlagenforschung denn überhaupt leisten?" Die Antwort lautet, daß wir ohne Grundlagenforschung keine gesunde Technik und Ökonomie betreiben können! Dies wäre ein Baum ohne Wurzeln, der nicht lange gedeihen könnte. Wenn das Geld knapp ist, erscheint es immer als einfachste Lösung, alles zu verschieben, was nur der weiteren Zukunft gewidmet ist. Aber wer so handelt, verpfändet die Zukunft.

under the control of humanity: If man does not develop such a product then this product does not exist. The great question is therefore: Are the organized institutions of humanity and the individual strength of mankind capable of making wise decisions about this path towards application? My conviction is that mankind and its institutions on the average make better and more certain decisions concerning the application of a natural law when they understand the basis of such a law of nature.

It is very easy to complain that certain influences of technology have complicated life. One must, however, compare such aggravations with the catastrophe which would arise if one attempted to feed, to clothe, to house, to transport and to protect the existing and future population of the world without further technical developments!

Technology has eased the exchange of information among people of all countries. A result is that secrets are more difficult to keep secret both in private and in public life. Although this becomes rather uncomfortable in private affairs, one must admit that internationally this circumstance can be an important step towards peace. The satellites which now encircle the earth have removed many secrecy barriers. The control of weapons in the world is imaginable because the satellites and radar can accomplish their observations above and through the Iron Curtain. The result of all these technical developments is that we now live in a much more open world than in the previous century.

The future of civilization is to a large extent dependent on progress in technology. In turn, the progress of technology depends on progress in basic research. Therefore throughout the world in which we live there is no alternative to the duty of human society to carry out scientific research intensively - the only question is how intensively.

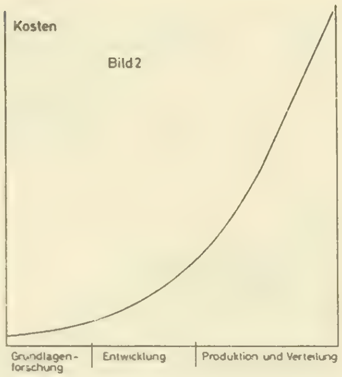
Basic research requires money and work. When the economy or industry are in difficulty one often hears the question,

Bild 2 zeigt schematisch, wie sich die Kosten längs der Entwicklungskette von der Grundlagenforschunng bis zur endgültigen Herstellung verteilen. Man sieht, daß die Grundlagenforschung nur einen winzigen Bruchteil der Gesamtentwicklungskosten verursacht. Auf der anderen Seite aber gibt es ohne die Grundlagenforschung das technische Endprodukt überhaupt nicht: Die Grundlagenforschung ist der Samen für alle technische Weiterentwicklung. Ein Beispiel hierzu: Das Prinzip des Linearbeschleunigers wurde vor dem Zweiten Weltkrieg entdeckt und mit einem Forschungsaufwand von ungefähr einer Million DM in die Wirklichkeit umgesetzt. Diese Entwicklung hat zu einem ganzen Industriezweig geführt, der Linearbeschleuniger zur Krebsbestrahlung herstellt. Der Gesamtpreis der bisher an Krankenhäuser gelieferten Linearbeschleuniger beträgt 10 Milliarden DM.

Durch theoretische und experimentelle Grundlagenforschung, dem ersten Glied unserer Entwicklungskette, werden sicherlich auch in der Zukunft neue Wahrheiten über die Natur entdeckt. Deshalb muß die Antwort auf die Frage "Grundlagenforschung - Fluch oder Segen?" Probleme der Moral und der Politik berücksichtigen und in Rechung stellen, wie die Gesellschaft auf Entdeckungen aus der Grundlagenforschung reagiert. Kann der Mensch die Resultate der Forschung in konstruktive Richtungen lenken und gleichzeitig die zerstörenden Folgen vermeiden?

Nirgends ist die Frage wichtiger als in der Militärpolitik. Die Natur hat uns die Mittel gegeben, die Zivilisation auf der Erde zu vernichten. Ich sage "die Natur", nicht "die Wissenschaft", denn ich bin überzeugt, daß sich jedes Geheimnis der Natur eines Tages offen zeigen wird. Die Kraft der Kernwaffen ist dieselbe wie die, welche die Sonne und die Sterne mit Brennstoff versorgt.

Zur Zeit gibt es ungefähr 50 000 Nuklearsprengkörper in der Welt, ungefähr gleichmäßig verteilt zwischen der NATO und dem Warschauer Pakt. Diese Menge ist viel zu groß, als daß sie im Kriegsfall eingesetzt werden könnte, ohne die Fortsetzung der Zivilisation aufs Spiel zu



"Yes, but can we afford basic research?" The answer is that without basic research or technology the economy cannot be healthy. This would be a tree without roots which cannot thrive for any length of time. If money is short it often appears to be the simplest solution to defer everything which only serves the long-range future. However, whoever chooses such a course mortgages the future.

Figure 2 shows schematically how costs are distributed along the development chain starting from basic research to eventual realization. One sees from Figure 2 that the costs of basic research are only a tiny fraction of the total cost of development. Yet without basic research the technical end product would not even exist; basic research is the seed for all further technical development.

Let me give an example. The principle of the linear accelerator was discovered before the Second World War and was reduced to practice at a research cost of about one million DM. This development has led to an industry which develops linear accelerators for cancer therapy at hospitals. The total price of linear accelerators developed for this purpose to date is roughly 10 billion DM. The first link of our development chain, that

setzen. Die Zahl der Sprengkörper ist viel größer als daß sie sich mit dem Argument der Abschreckung rechtfertigen ließe. Wir wissen das, die Amerikaner wissen das, und die Russen wissen das. Trotzdem ist die Zahl der Atombomben in diese unvorstellbare Höhe gestiegen. Wie konnte das geschehen? Darüber ist viel geschrieben worden. Der Hauptgrund ist, daß sich die Staaten bei der Anschaffung und Produktion neuer Waffen vor allem politisch und nicht wissenschaftlich rechtfertigen. Bild 3 zeigt als Beispiel die Ost-West-Jagd nach immer mehr Nuklearsprengkörpern, die von den Amerikanern beziehungsweise den Sowjets mit langreichweitigen (strategischen) Waffensystemen abgeschossen werden können. Solch ein Wettlauf läßt sich nur rechtfertigen, wenn die Waffen Symbole der Stärke geworden sind, ohne Bezug auf die Realität ihres militärischen Nutzens. Wir Wissenschaftler haben die ernste Plicht, den Politikern immer wieder die physische Realität der Kernwaffen vor Augen zu halten. Wenn im politischen Entscheidungsprozeß die wissenschaftliche Realität der Waffen vergessen wird, dann läßt sich die verhängnisvolle Frage "Wann ist genug?" gar nicht beantworten. In diesem Sinne kann die Wissenschaft ein Segen sein, wenn es ihr gelingt, die Politiker und die Öffentlichkeit davon zu überzeugen, daß die physikalische Realität der Kernwaffen, nämlich ihre zerstörende Kraft, so verheerend ist, daß sich für das Ziel einer wirksamen Abschreckung nur eine sehr kleine Zahl rechtfertigen läßt. Im allgemeinen wird das Handeln der Politiker durch Vorstellungen und nicht durch Realität bestimmt, der Naturwissenschaftler dagegen versucht, die Wahrheit der Natur, das heißt die objektive Realität, zu erkennen.

Man kann leicht viele andere Beispiele finden, die belegen, daß die Anwendung der Wissenschaft auf die Technologie entweder gutartig oder schädlich ist. Was letzlich herauskommt, hängt davon ab, ob im gesellschaftlichen Entscheidungsprozeß Zusammenhänge klar erkannt sind und ob darauf logisch reagiert wird oder ob sie in diesem Prozeß in den Hintergrund gerückt werden.

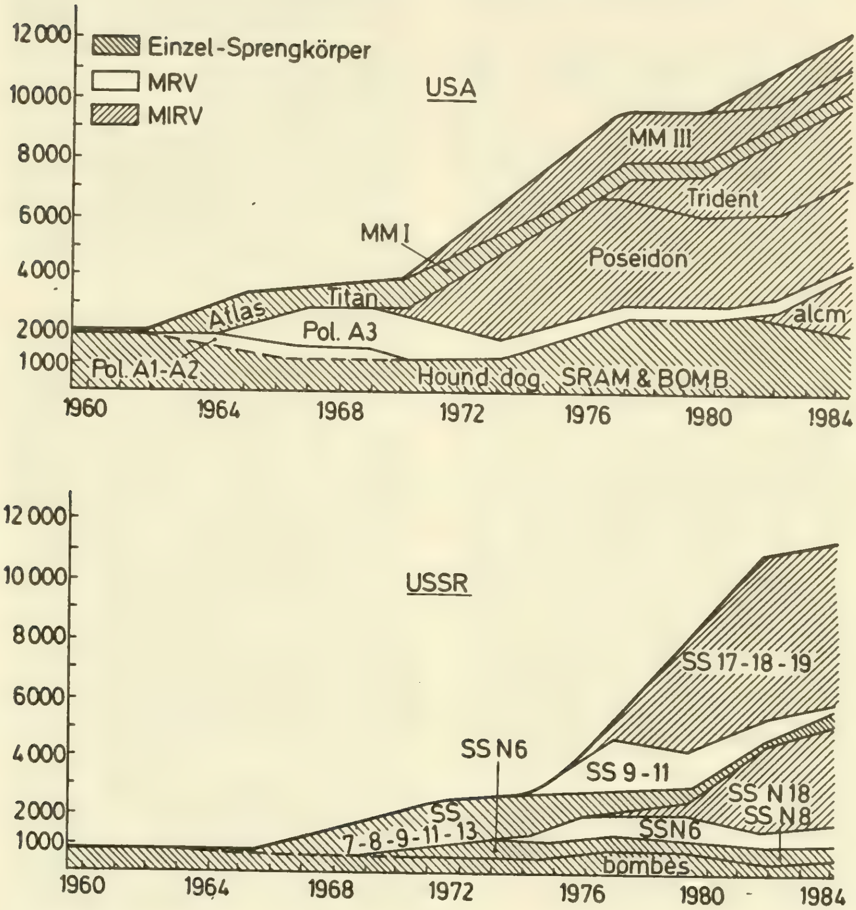
is theoretical and experimental basic research, will surely, although in the future, uncover new truth about nature. Therefore the answer to the question "Basic Research - Curse or Blessing?" deals with problems of morality and the politics of society as to how it will react to these discoveries. Can mankind direct the results of research into constructive directions and avoid simultaneously the destructive consequences?

Nowhere is this question more important than in military policy. Nature has given us the means to destroy civilization on earth. I am saying here "nature" and not "science" since I am persuaded that the secrets of nature will exhibit themselves openly sooner or later. The source of energy for nuclear weapons is the same which furnishes fuel to the sun and the stars.

At this time there exist roughly 50,000 nuclear weapons in the world, roughly evenly divided between NATO and Warsaw Pact. This number is much too large to be applicable in any way in case of war without threatening the future of civilization. The number of nuclear explosives is much larger then can be justified for deterrence of war. We know this, the Americans know this and the Russians know this. Nevertheless, the number of atomic bombs has risen to this unimaginable figure. How did it happen? Much has been written about this. The principal reason is that states, whenever they acquire new weapons, justify the need, above all politically and not scientifically. Figure 3 shows as an example the mutual competition in increasing the number of nuclear weapons which can be delivered with long-range strategic weapons systems between the Americans and the Soviets. Such a competition can only be justified when weapons have become symbols of strength without reference to the reality of their military usefulness. We scientists have the earnest duty to repeatedly draw the attention of politicians to the physical realities of nuclear weapons. If in the political process the scientific reality of weapons is forgotten, then the fateful

Bild 3

Anzahl der Strategischen Sprengkörper



Wir müssen lernen, daß sich die Gesetze der Natur nicht durch Staatsbeschlüsse erzwingen lassen; der Mensch kann die Fundamentalgesetze der Natur weder ändern noch verbergen. Wir kennen viele Beispiele in der Geschichte, wo eine staatliche oder religiöse Macht beschloß, ein Naturgesetz sei unbequem. Das Resultat war im allgemeinen tragisch.

Im Mittelalter war Galilei aufgrund seiner astronomischen Beobachtungen überzeugt, daß die Erde um die Sonne läuft und nicht das Zentrum der Welt ist. Doch mußte er diese Meinung unter Drohung von Folter und Tod widerrufen. In der Sowjetunion wurden die unsinnigen Theorien des Pseudobiologen Lysenko zum Staatsdiktum erhöht, um eine unselige Agrarpolitik zu rechtfertigen. Nur nach einem mutigen Kampf der Sowjetischen Akademie der Wissenschaften war es schließlich wieder erlaubt, in der Sowjetunion Biologie und Genetik im wissenschaftlichen Sinn zu lehren.

Zwischen 1933 und 1945 war es in Deutschland strengstens verboten, Einsteins Relativitätstheorie zu lehren. Heute bildet die Relativitätstheorie die Basis für viele Gebiete der Technik; ohne Relativitätstheorie gäbe es keine Hochleistungselektronenröhren, keine intensive Röntgenstrahlung, keine Hochenergiebeschleuniger und deshalb kein DESY! Und der verbrecherische Beschluß des Staates, im Widerspruch zur Wissenschaft einer menschlichen Rasse eine fundamentale Überlegenheit zuzuschreiben, führte zu der größten Tragödie des deutschen Volkes und der Menschheit.

Heute zittert die Menschheit vor der drohenden Macht der vielen Tausenden von Kernwaffen. Trotzdem hat der Präsident der Vereinigten Staaten vorgeschlagen, daß ein neuer Verteidigungsschirm die existierenden Kernwaffen "überholt und wirkungslos" (obsolete and impotent) machen sollte, obwohl die ungeheure Wirkung der heutigen Kernwaffen der Angriffsmacht einen gewaltigen Vorsprung gegenüber der sich verteidigenden Macht gibt. Was die Wissenschaft erfunden hat, kann nicht durch offiziellen Beschluß unerfunden gemacht werden!

question "When is enough enough?" cannot be answered. In this sense science can be a blessing if it succeeds in convincing politicians and the public that the physical realities of nuclear weapons, that is their destructive power, is so overwhelming that for the goal of deterrence only a very small number can be justified. Generally the actions of politicians are determined by perceptions and not by reality. The scientist attempts to single out the truth in nature, that is the objective reality.

One can easily find many other examples where the application of science to technology is either beneficial or damaging; what actually results depends on whether the human decision process recognizes clearly the scientific circumstances and reacts logically to them, or whether the process pushes the scientific facts into the background.

We must learn that the forces of nature cannot be coerced by the state; man can neither change nor hide the fundamental laws of nature. We know many examples of history when a governmental or religious power decided that a law of nature was uncomfortable: The result in general turned out to be tragic. In the Middle Ages Galilei became convinced through preceding astronomical observations that the earth orbits around the sun and was not the center of the world. However he had to recant this opinion under threat of torture and death. In the Soviet Union the senseless theories of the pseudo-biologist Lysenko were elevated to an edict of the state in order to justify the ill-advised agricultural policy of the state. Only after a courageous fight on the part of the Soviet Academy of Sciences was it again permitted to teach biology and genetics in Russia in the scientific sense.

Between 1933 and 1945 it was rigidly forbidden to teach in Germany the Theory of Relativity of Einstein. Today the Theory of Relativity forms the basis for many fields of technology. Without the Theory of Relativity there would be no high-powered electron tubes, no intensive

So ähnlich ist es beim Umweltschutz. Es ist sinnlos, Wissenschaft und Technologie als Urübel der Verschmutzung der Natur anzuklagen; die Ursache ist in unklugen Entscheidungen der menschlichen Gesellschaft zu suchen. Wir brauchen die Wissenschaft - sowohl die Grundlagenforschung als auch die Entwicklung von spezifischen Maßnahmen -, um unsere Umwelt wieder sauberer zu machen.

Mit all diesen Beispielen wollte ich zeigen, daß nur mit Grundlagenforschung, die zum besseren Verständnis der Natur führt, die wachsende Zahl von Menschen ohne große Leiden und Katastrophen auf diesem Planeten überhaupt leben kann. Die Grundlagenforschung ist deshalb absolut notwendig für die Zukunft unserer Zivilisation. Mit Hilfe der Wissenschaft ist es möglich, daß wir wenigstens in Harmonie mit unserer natürlichen Umwelt leben können. Aber dies kann nur Realität werden, wenn unsere Staatsbürger den Rat der Wissenschaft kritisch aufnehmen. Im fundamentalen Sinn ist die Wissenschaft kein Fluch, aber sie kann nur zum Segen werden, wenn sie sorgfältig gepflegt und ausgenutzt wird. Leider versuchen viele Politiker und weite Teile der Gesellschaft, nur auf die großen Möglichkeiten der Wissenschaft zur industriellen Nutzung hinzuweisen, aber gleichzeitig die Aussagen derselben Wissenschaft über die Grenzen des Wachstums und die Notwendigkeit der Beschränkung der militärischen Macht zu ignorieren. Die Wahrheit der Naturgesetze ist aber unteilbar: Der Mensch kann sich nicht die bequemen Naturgesetze herauspicken und die unbequemen ignorieren.

In den vorangehenden Bemerkungen haben wir die Rolle der Wissenschaft als ein zweischneidiges Schwert beschrieben. Wir haben den Schluß gezogen, daß die Forschung einschließlich der Grundlagenforschung eine Notwendigkeit der modernen Gesellschaft ist und die Verbesserung der Lebensqualität der ganzen Welt ermöglicht, aber nicht sichert. DESY kann stolz sein, dabei eine sehr wichtige Rolle zu spielen. Diese Aussage gilt nicht nur für die Vergangenheit, sondern auch für die Zukunft. Die neue Maschine

X-rays, no high energy accelerators and therefore no DESY. And the criminal decision by the State, in contradiction to science, to attribute to one human race a fundamental superiority led to the greatest tragedy of the German people and humanity.

Today humanity trembles before the threatening might of many thousands of atomic weapons. Nevertheless the President of the United States has proposed that a new defensive umbrella should make the existing nuclear weapons "obsolete and impotent". This proposal was made, notwithstanding the fact that the immense power of today's nuclear weapons has given the offensive power an enormous advantage against defensive measures. What science has invented cannot be uninvented through offical decree.

The situation is similar in respect to environmental protection. It is senseless to accuse science and technology as the basic root of the pollution of nature; one should look for the cause in unwise decisions of human society. We need science, both basic research and the development of specific remedies, in order to clean up our environment.

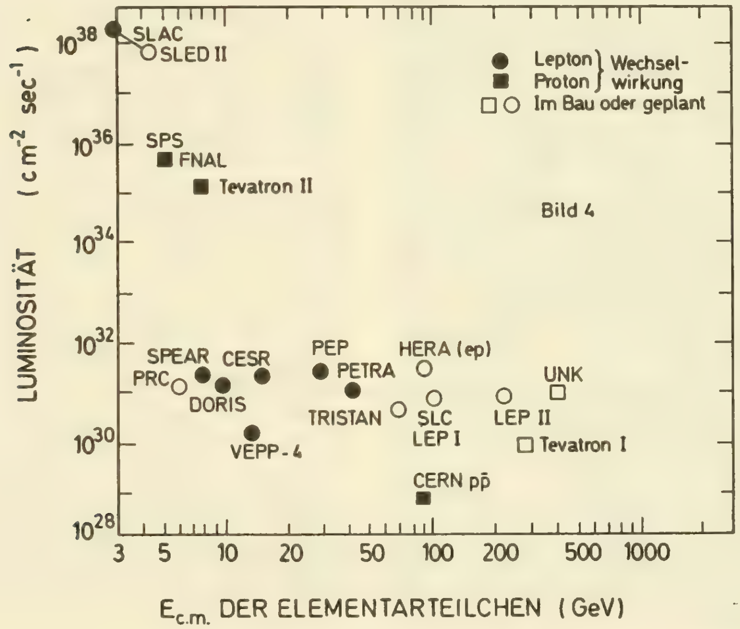
With all these examples I am trying to demonstrate that without basic research which leads to a better understanding of nature the growing number of people cannot be accommodated on this planet without great suffering and catastrophe. Basic research is therefore absolutely necessary for the future of civilization. With science it is at least possible that we can live in harmony with the natural world. However, this can only become reality when our citizens listen critically to scientific advice. In a fundamental sense science is not a curse but it can only become a blessing if it is treated and explored carefully. Unfortunately many politicians and many parts of society attempt to exploit only the great possibilities of science for industrial application and they hide simultaneously the results of the same science for the limits of growth and for the necessity of restricting military might. The truth of the laws nature is inseparable: Man cannot pick out those

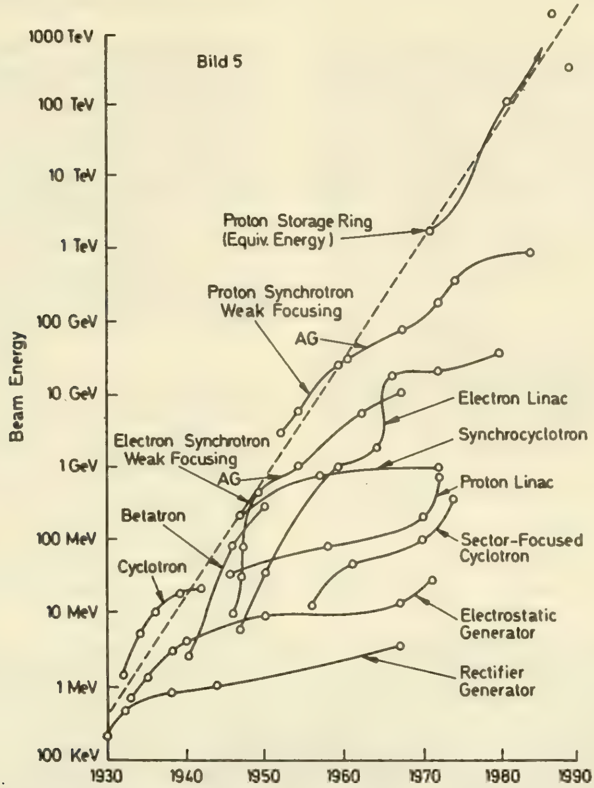
HERA wird DESY eine einzigartige Gelegenheit schaffen, neue Fundamentalresultate in der Teilchenphysik zu finden. HERA ist die einzige Kollisionsmaschine der Welt für Elektronen und Protonen.

Mit diesem Apparat kann die Struktur des Protons in höchster Präzision erforscht werden, da die Struktur und die Wechselwirkung des Elektrons wohlbekannt ist. Es ist interessant festzustellen, daß die drei großen europäischen Kollisionsmaschinen - HERA, die Proton-Antiproton-Anlage SPS im CERN und die erste Stufe von LEP im CERN - alle dieselbe Kollisionsenergie haben, wenn man die maximale Energie der am Stoß beteiligten Grundbausteine (Leptonen und Quarks) betrachtet (siehe Bild 4).

laws of nature with which he feels comfortable and ignore those which he considers uncomfortable.

In the foregoing remarks we have described the role of science as a two-edged sword. We have drawn the conclusion that research including basic research is a necessity of modern society and that it makes possible the improvement of the quality of life within the whole world but it does not assure such improvement. DESY can be proud to have played a very important role in this undertaking. This statement applies not only to the past but also to the future. The new machine HERA will provide a unique opportunity to DESY to find new fundamental results in particle physics. HERA is the only collider in the world in which electrons and protons meet.





Die Zukunft von Laboratorien wie DESY und meinem Heimatinstitut SLAC hängt von der kontinuierlichen Selbsterneuerung ab. Als DESY vor 25 Jahren gegründet wurde, konnte sich niemand die Zukunft mit DORIS, PETRA und HERA vorstellen. Wie Bild 5 illustriert, wird der Fortschritt der Hochenergiephysik durch Erfindungen neuer Beschleunigerverfahren bestimmt. Jede neue Methode der Beschleunigung von Elementarteilchen macht es möglich, die Obergrenze der erreichbaren Energie weiter zu verschieben. Doch kann mit jeder Methode nur ein gewisser Fortschritt bewirkt werden, ehe sie zu teuer

With this apparatus the structure of protons can be explored with highest precision since the structure and interaction of electrons are well-known. It is interesting that the three large European colliders - HERA, the CERN proton-antiproton adaptation of the supercollider (SPS), and the first step of the LEP machine at CERN all lead to the same collision energies if one measures the energy with which the fundamental building blocks (leptons, quarks) collide. This is illustrated in Figure 4.

The future of laboratories like DESY and my own institution SLAC depends on

wird, und wieder eine neue Technik erfunden und eingeführt werden muß. DESY hat an mehreren dieser technischen Sprünge mitgearbeitet und ich bin überzeugt, daß DESY auch zu den nächsten Sprüngen beitragen wird. Ich weise darauf hin, daß die Systematik dieser Entwicklungen zeigt, wie die Grundlagenforschung dem Fortschritt der Technik dient, wie aber auch umgekehrt die Technik zum Fortschritt der Wissenschaft nötig ist. Wissenschaft und Technik stehen in einer wechselseitigen, symbiotischen Verbindung.

Ich möchte schließen mit einem Glückwunsch an DESY, ein Laboratorium, das ein ganzes Vierteljahrhundert hindurch eine großartige Rolle in diesem großartigen Abenteuer unserer Zeit gespielt hat.

continuing renewal. When DESY was founded 25 years ago no one could imagine the future with DORIS, PETRA and HERA. As is illustrated in Figure 5, the progress of high energy physics is paced by inventions of new means of acceleration. Each new method of acceleration of elementary particles makes it possible to raise the attainable energy limit. Yet each one method can only lead to a certain progress until it becomes too expensive; then a new technology has to be invented and introduced. DESY has contributed to many of these jumps; I believe that DESY will also contribute to the subsequent advances.

I am pointing out these facts to demonstrate the systematics of these developments which show how basic research leads to progress of technology, but also how, conversely, that new technology is necessary for the progress of research. Science and technology have mutually reinforcing symbiotic connection.

I would like to conclude with congratulations to DESY, a laboratory which has played such a large role through a quarter century in this great adventure of our time.

Foto DESY Jurgen Schmidt (57898/20)

Historischer Rückblick

von Prof. Willibald Jentschke

Herr Bundespräsident,
Herr Präsident der Bürgerschaft,
meine Herren Senatoren,
sehr geehrte Damen und Herren,
liebe Freunde!

Ich möchte hier keinen umfassenden historischen Rückblick auf DESY geben. Ich möchte nur einige Worte zur Gründung von DESY sagen.

Vom 11. bis 23. Juni 1956 fand in Genf ein internationales Symposium für Hochenergiephysik und Hochenergiebeschleuniger statt. Aus der Bundesrepublik Deutschland nahmen daran folgende Experimentalphysiker teil: Wolfgang Gentner, Wolfgang Paul, Wolfgang Riezler, Christoph Schmelzer, Arnold Schoch und Wilhelm Walcher. Ich selbst kam direkt aus den USA, um nach dieser Konferenz meine Tätigkeit am physikalischen Institut der Universität Hamburg aufzunehmen. Wir haben damals die unbefriedigende Lage der Hochenergiephysik in der Bundesrepublik erörtert. Zur Verbesserung der Situation beschlossen wir, die Errichtung eines 6-GeV-Elektronen-Synchrotrons vorzuschlagen. Dieser Bau sollte in Anlehnung an ein ähnliches Projekt durchgeführt werden, das in den USA von den beiden Forschungszentren Massachusetts Institute of Technology und Harvard University unter der Leitung von Stanley Livingston gerade begonnen worden war. Diese Wahl ermöglichte es, im Prinzip an die Vorfront der Forschung vorzustoßen. Sie war neu in Europa und sicherte uns die nötige Hilfe durch die enge Zusammenarbeit mit der Livingston-Gruppe.

Die Weiterentwicklung dieses Vorschlages führte drei Jahre später zur Gründung der Stiftung "DESY, Deutsches Elektronen-Synchrotron". Diese Entwicklung war nur dadurch möglich, daß sich Persön-

Historical Review from

Prof. Willibald Jentschke

Herr Bundespräsident,
Herr Präsident der Bürgerschaft,
Herr Senator,
Ladies and Gentlemen,
Dear Friends!

I don't want to give a comprehensive historical review here. I just say a few words on the founding of DESY.

From the 11th to the 23rd July 1956 an international symposium for high energy physics and high energy accelerators was held in Geneva. The following experimental physicists took part from the Federal Republic of Germany: Wolfgang Gentner, Wolfgang Paul, Wolfgang Riezler, Christoph Schmelzer, Arnold Schoch, and Wilhelm Walcher. I came directly from the U.S.A. to take up my post at the Physics Institute of the University of Hamburg after the conference. We discussed the unsatisfactory situation in the Federal Republic with regard to high energy physics. To improve this we decided to propose a 6 GeV electron synchrotron. The project was assisted by a similar one which had just been started in the U.S.A. by the Massachusetts Institute of Technology and Harvard University under the leadership of Stanley Livingston. This choice made it possible in principle to venture to the front rank of research. It was new in Europe, and guaranteed the necessary support through the close cooperation with Livingston's group.

Further development of this proposal led three years later to the establishment of the foundation "DESY, Deutsches Elektronen-Synchrotron". This was only possible, because various people in politics, management and science were courageous enough to pursue the project without being hindered by bureaucracy. Without this readiness to help us in all situations we would never have reached our goal. This confidence in our propo-

lichkeiten aus Politik, Verwaltung und Wissenschaft fanden, die sich mutig und ohne Bürokratismus für die Durchführung dieses Projektes einsetzten. Ohne diese aufgeschlossene Bereitwilligkeit, uns in jeder Situation zu helfen, wären wir nie ans Ziel gekommen. Denn dieses Vertrauen in unsere Vorschläge war keineswegs selbstverständlich, lagen doch damals in Deutschland wirklich kaum Kenntnisse über den Bau eines solchen Großbeschleunigers vor.

Ich möchte deshalb im Namen von DESY noch einmal meinen Dank aussprechen, zunächst dem Senat der Freien und Hansestadt Hamburg und ihrer Bürgerschaft, dem früheren Bundesministerium für Atomenergie und Wasserwirtschaft - dem jetzigen Bundesministerium für Forschung und Technologie -, dem Parlament mit seinen Ausschüssen, den Landesregierungen und den Länderparlamenten, dem Verwaltungsrat von DESY mit seinen Mitgliedern von Bundes- und Landesseite. Ich möchte aber auch sehr herzlich der alten mathematisch-naturwissenschaftlichen Fakultät danken, dem Fachbereich Physik und auch dem früheren Rektor der Universität, der uns damals sehr geholfen hat, und dem jetzigen Universitätspräsidium. Ich danke auch der Deutschen Physikalischen Gesellschaft, deren frühzeitige Unterstützung wesentlich zu dem Gelingen des Projektes beigetragen hat. Ich möchte aber auch den verschiedenen Behörden des Stadtstaates Hamburg und des Bundes danken, welche die Bedingungen geschaffen hatten, die das Entstehen dieses Forschungszentrums zuließen.

Für den Erfolg von DESY war die uneigennützige Hilfe, die DESY von Livingston und seiner Gruppe erfuhr, wesentlich. Daneben sei ebenfalls der Unterstützung durch Panofsky und Hofstadter von der Stanford University gedacht. Auch mit CERN war von Anfang an ein reger Austausch vorhanden. In diesem Zusammenhang möchte ich die Namen John Adams, Mervin Hine, Arnold Schoch, Christoph Schmelzer und Wolfgang Schnell an Stelle von vielen anderen nennen.

Foto DESY Jurgen Schmidt (37899/21)

sals was certainly not self-evident, as at that time there was hardly any knowledge in Germany on the building of such a large accelerator.

Therefore, in the name of DESY, I would once again like to thank the Senate of the Freie und Hansestadt Hamburg and the City Parliament, the former Ministry of Atomic Energy and Water Supply, the present Ministry of Research and Technology, the State Parliament and its committees, the governments and parliaments of the different States, and the Administration Board of DESY with its members from the Federal Republic and from Hamburg. I would also like to thank heartily the old science faculty, the Fachbereich Physik and the former rector of the university, who helped us a great deal at that time, and the present presidency. I also thank the German Physical Society whose early support contributed significally to the success of the project. I would also like to thank the various authorities of the city of Hamburg and the Federal government who created the necessary conditions, which allowed the emergence of this research centre.

Lassen sie mich zum Abschluß drei Bilder zeigen.

Das erste gibt die Unterzeichnung des Staatsvertrags zur Gründung der Stiftung "DESY, Deutsches Elektronen-Synchrotron" wider, die am 18. Dezember 1959 durch den Ersten Bürgermeister der Freien und Hansestadt Hamburg, Max Brauer (rechts) und den Minister für Atomenergie und Wasserwirtschaft, Professor Siegfried Balke (links) im Hamburger Rathaus erfolgte. In dem Vertrag wurde die Finanzierung des Baus dieses Hochenergie-Beschleunigers und der dazu gehörenden Laboratorien von DESY bis zu einer Summe von 60 Millionen DM geregelt.

For the success of DESY the unselfish help from Livingston and his group was essential. The support of Panofsky and Hofstadter must also be mentioned. Besides that we had close contact with CERN and in this connection I would like to mention the names John Adams, Mervin Hine, Arnold Schoch, Christoph Schmelzer and Wolfgang Schnell among many others.

To close let me show three pictures. The first one shows the signing of the treaty setting up the foundation "DESY, Deutsches Elektronen-Synchrotron". It was done on 18th December 1959 by the Hamburg Mayor Max Brauer (right) and the Federal German Atomic Energy Minister Siegfried Balke (left) in the Hamburg Rathaus. In this contract the financing of the building of this high energy accelerator and the necessary laboratories at DESY was regulated up to a total of 60 million DM.

Foto DESY-Archiv (1666)

Foto Staatliche Landesbildstelle Hamburg, Freigabe-Nr. L548

Das zweite Bild stellt das ursprüngliche Gelände in Hamburg-Bahrenfeld dar, vor dem Bau des Bauschleunigers. Es handelt sich um einen ehemaligen Militär- und späteren Sportflugplatz. Das Gelände wurde 1957 von den Bundesministerien für Verteidigung und Finanzen der Hansestadt Hamburg für den Bau des Beschleunigers zur Verfügung gestellt. Die Aufnahme enstand während einer Sportveranstaltung "Flugtag Altona" zwischen 1929 und 1933.

The second picture shows the original site in Hamburg-Bahrenfeld before the construction of the accelerator. It was a former military and a later sports flying aerodrome. The area was made available for Hamburg in 1957 by the Federal German Defence and Finance Ministries. This picture was taken during the sports meeting "Flugtag Altona" between 1929 and 1933.

Foto DESY/Bildflug (35271), Freigabe-Nr. 262/81 LA HH

Das dritte Bild zeigt DESY in seiner derzeitigen Ausbaustufe. Zu dem kreisförmigen Elektronen-Synchrotron sind die beiden Elektron-Positron-Speicherringe DORIS und PETRA hinzugekommen, an denen insgesamt sechs Gruppen mit jeweils 80 bis 100 Physikern parallel experimentieren. Der PETRA-Ring von 2,3 km Umfang umschließt das DESY-Gelände, während der Tunnel für die Elektron-Proton-Anlage HERA nur zu etwa 20% unter DESY-eigenem Territorium verlaufen wird. Außerdem werden in zwei Hallen Experimente mit der Synchrotronstrahlung aus den unterschiedlichsten Forschungsgebieten durchgeführt.

Ich glaube, daß keiner der Physiker, die im Jahr 1956 in Genf den Bau des Elektronen-Synchrotrons vorschlugen, auch nur im Entferntesten ahnten, was aus DESY nach 25 Jahren werden würde.

The third picture shows the present state of DESY. In addition to the circular electron synchrotron there are the two electron-positron storage rings, DORIS and PETRA. Six groups work on them, each with between 80 and 100 experimental physicists. While the PETRA ring with a circumference of 2.3 km almost encloses the DESY site, the tunnel for the HERA electron-proton collider will run under the DESY area for only about 20% of its length. Besides that in two halls many groups from different research fields carry out experiments with synchrotron radiation.

I think that none of the physicists who proposed the construction of the electron synchrotron in 1956, would have imagined in their wildest dreams, how DESY would develop over its 25 years history.

Schlußwort von

Prof. Volker Soergel
Vorsitzender des DESY-Direktoriums

Herr Bundespräsident,
verehrte Anwesende!

Es bleibt mir zunächst der Dank an alle, die heute zu uns gesprochen haben, für die vielen guten Wünsche und die vielen Gedanken, die wir mitbekommen haben bei dieser Geburtstagsfeier.

Wir feiern heute das 25jährige Bestehen von DESY. An diesem Tag wollen wir uns natürlich auch an das erinnern, was bei DESY erreicht worden ist, an das, was die Erfolge dieses Laboratoriums gewesen sind, die Erfolge der Wissenschaftler und aller Mitarbeiter, die hier geforscht und gearbeitet haben. Heute nachmittag wird im Rahmen eines wissenschaftlichen Kolloquiums Gelegenheit sein, sich über diese Erfolge Rechenschaft zu geben. Ich begrüße hier die Vortragenden dieses Kolloquiums: Herr Prof. Sands aus Santa Cruz wird über Beschleuniger reden, Herr Prof. Meyer aus Wuppertal über die Ergebnisse der Hochenergiephysik an den DESY-Beschleunigern, Herr Prof. Steinmann aus München über Ergebnisse der Forschung mit Synchrotronstrahlung und Herr Prof. Fritzsch aus München über die theoretischen Vorstellungen der Elementarteilchenphysik.

An einem solchen Tag wie heute soll man aber auch über die Zukunft etwas sagen: Wie geht es weiter nach den ersten 25 Jahren? Nun, für die Elementarteilchenphysik bei DESY kann man wohl sagen, daß die Zukunft bereits begonnen hat. Seit Mai bauen wir HERA. Wir sind froh und dankbar, daß die Bundesregierung und der Hamburger Senat ihre Zustimmung zum Bau dieses großen Projekts hier in Hamburg gegeben haben. Am 6. April haben Herr Minister Riesenhuber und Herr Senator Sinn (Ich begrüße Herrn Sinn heute sehr herzlich bei uns.) bei DESY in einer Feierstunde die HERA-Vereinbarung zwischen Bonn und Hamburg unterzeichnet.

Closing Address from

Prof. Volker Soergel
Chairman of the DESY Directorate

Herr Bundespräsident,
Ladies and Gentlmen!

I must first of all thank all those who have addressed us today, for the many good wishes and the thoughts which we have recieved at our birthday celebration.

We are celebrating the 25th anniversary of DESY today. We should, of course, remember what has already been achieved at DESY, what have been the successes of this laboratory, the successes of the scientists and staff who have researched and worked here. This afternoon in the framework of a scientific colloquium there will be an opportunity to give an account of these successes. I welcome the lecturers at this colloquium: Prof. Sands from Santa Cruz will talk about accelerators; Prof. Meyer from Wuppertal on the high energy physics results from the DESY accelerators; Prof. Steinmann from Munich on the synchrotron radiation results and Prof. Fritzsch from Munich on the theoretical ideas in elementary particle physics.

However, on an occation such as this one should also say something about the future: How are we going to continue after the first 25 years? For elementary particle physics at DESY one can say that the future has already begun. We have been building HERA since May. We are glad and thankful that the Federal government and the Hamburg senate have given their approval for the building of this large project here in Hamburg. On the 6th April Minister Riesenhuber and Senator Sinn (I welcome Herrn Sinn heartily here today.) signed the HERA contract between Bonn and Hamburg during a ceremony held here at DESY.

The building of this large accelerator project will need all the available

Der Bau dieses großen Beschleuniger-Projekts wird in den kommenden Jahren alle Kräfte bei DESY beanspruchen. Wenn HERA fertiggestellt ist, dann stehen uns und den Physikern aus Deutschland und aus aller Welt, die hier gemeinsam forschen werden, viele Jahre interessanter Forschungsarbeit bevor. Herr Panofsky hat schon erwähnt, wie einmalig die Maschine HERA sein wird.

Mit HERA betreten wir Neuland in verschiedener Beziehung: physikalisches Neuland, wie es Herr Panofsky ausgeführt hat, technologisches Neuland dadurch, daß wir die Supraleitung großtechnisch in Dimensionen einsetzen, in denen sie bisher in Europa nicht eingesetzt wurde. Dieser Einsatz der Supraleitung bei dem Protonen-Ring auf seiner vollen Länge von 6 km erfordert eine intensive und gute Entwicklungsarbeit, die wir gemeinsam mit der Industrie leisten müssen.

Wir betreten auch Neuland bezüglich der internationalen Zusammenarbeit. Wir wollen nämlich versuchen, zum ersten Mal einen großen Beschleuniger in der Weise zu bauen, wie man bisher Experimente gebaut hat, und zwar in der Weise, daß Partner miteinander die Maschine bauen, ihre Teile, ihre Komponenten zu Hause fertigen und dann nach Hamburg liefern, um sie in das gemeinsame Projekt einzubringen. HERA wird überwiegend von der Bundesrepublik Deutschland und von Hamburg finanziert. Aber es sind namhafte Beiträge zu Komponenten von ausländischen Instituten und Forschungsorganisationen fest eingeplant.

Ein ganz besonders bedeutender Beitrag zu der HERA-Maschine ist von Italien, von dem Istituto Nationale di Fisica Nucleare, in Aussicht gestellt worden. Ich freue mich deswegen besonders, daß seine Exzellenz, der Botschafter von Italien, Prof. Ferraris, heute bei uns ist und uns mit seiner Anwesenheit zeigt, welche Bedeutung der HERA-Beitrag für seine Regierung und in seinem Land hat.

Wir betreten noch in einer anderen Hinsicht Neuland. In der Abbildung sehen Sie das Synchrotron DESY, dessen Bau vor

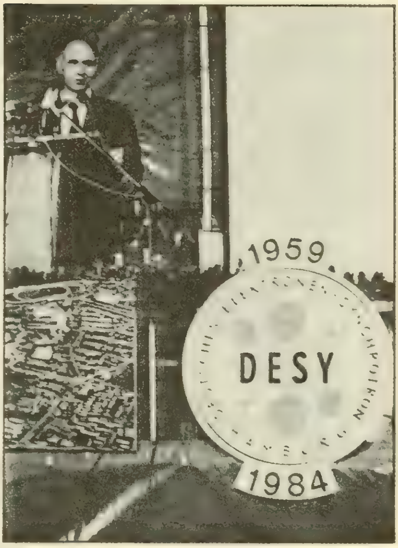


Foto DESY-PR Florian Becker

strength at DESY in the coming years. When it is finished we and physicists from Germany and from the whole world who will research together here, will have many years of interesting research in front of them. Herr Panofsky has already mentioned the uniqueness of HERA.

With HERA we are treading new ground in different areas: new ground in physics as Herr Panofsky has outlined, new ground in technology as we will be using superconductivity in large dimensions, such as has not been employed in Europe before. This use of superconductivity in the proton ring for the whole of the 6 km length demands intensive and good development work together with industry.

We are also breaking new ground for international cooperation. We want to try, for the first time, to build an accelerator in the same way as one has built experiments up to now. Partners will build the machine together, con-

25 Jahren beschlossen worden ist, und den Speicherring PETRA, der jetzt betrieben wird und der ungefähr die Grenze des DESY-Geländes bildet. Der HERA-Speicherring reicht weit über die Grenzen von DESY hinaus und in das Stadtgebiet von Hamburg hinein. Wir betreten hier also dadurch Neuland, daß wir eine Anlage der Art und der Größe von HERA mitten in einer großen Stadt bauen, deren Experimentierhallen mitten in der Stadt liegen und deren Tunnel auch unter bewohnten Gebieten verläuft.

Wir sind sehr dankbar dafür, daß es die Stadt Hamburg und ihre politischen Institutionen ermöglicht haben, daß wir HERA hier in Hamburg bauen und somit auch hier mitten in der Stadt experimentieren können. Das hat auch einen ganz praktischen und wirtschaftlichen Nutzen; auf

structing their components at home and then delivering them to Hamburg to add them to the common project. HERA will be predominantly financed from the Federal Republic of Germany and Hamburg, but significant contributions to components from foreign institutes and research organizations are firmly planned.

A particularly significant contribution to the HERA machine from Italy, the Istituto Nationale di Fisica Nucleare, is in prospect. I am therefore very glad that His Excellency, the ambassador from Italy, Prof. Ferraris is here today, and through his presence he shows the importance which his government attaches to the HERA construction in his country.

We are also breaking new ground in another aspect: In the figure you see the

diese Weise können wir nämlich die existierenden Beschleuniger, zum Beispiel PETRA, als Einschuß-Maschinen benutzen und dies Potential früherer Investitionen, das hier bei DESY zur Verfügung steht, vollständig für die neue Anlage einsetzen. Mit HERA werden wir in Europa, wie schon jetzt, so auch im kommenden Jahrzehnt zwei Hochenergiezentren haben, CERN in Genf und DESY in Hamburg, und somit können wir komplementär Forschung betreiben, wie es Herr Panofsky vorhin beschrieben hat. Soweit zur Zukunft der Elementarteilchenphysik bei DESY.

Lassen Sie mich noch ein kurzes Wort sagen zur Zukunft unseres zweiten wichtigen Forschungsgebiets, der Arbeit mit der Synchrotronstrahlung am DORIS-Speicherring. DORIS ist heute eine der besten Röntgenquellen, eine der besten Synchrotronstrahlungsquellen der Welt. Wir haben hier ein hervorragend ausgestattetes Laboratorium, das insbesondere für die Röntgenphysik genutzt wird. Seit Eröffnung des Hamburger Synchrotronstrahlungslaboratoriums im Jahr 1981 hat die Zahl der Nutzer einige hundert Wissenschaftler aus Deutschland, die meisten von deutschen Universitäten, erreicht und der Bedarf an und die Nachfrage nach dieser wertvollen Strahlungsquelle nehmen laufend zu.

DESY hat nun ein Ausbauprogramm in Angriff genommen, das die Qualität der Strahlen durch den Einbau sogenannter Wigglermagnete und die Zahl der Experimentierplätze vergrößert, um so auch für die nächste Dekade ein gutes Laboratorium zur Verfügung zu stellen. Wir sind froh, daß unsere Stifter und unsere Geldgeber, die Regierung in Bonn und der Hamburger Senat, in den kommenden Jahren einem Personalausbau zugestimmt haben, um dieses Ausbauprogramm möglich zu machen.

Die längerfristige Zukunft der Synchrotronstrahlung wird von verschiedenen Faktoren beeinflußt. Zum einen wird sie davon abhängen, ob und wo eine europäische Röntgenquelle gebaut wird, zum anderen, wie lange DORIS noch in dem Maße wie heute von den Elementarteilchenphysikern gefragt ist. Jetzt wird die Maschine ja gemeinsam von den Experimentatoren,

synchrotron, DESY, the building of which was agreed to 25 years ago, and the storage ring PETRA, which is now being operated here, and roughly forms the boundary of the DESY site. The HERA storage rings stretch well beyond the limits of DESY into the city of Hamburg. That we are building an apparatus of the type and size of HERA, whose experimental halls lie in the middle of a large city and whose tunnel runs under inhabited areas, is also breaking new ground.

We are also very thankful that the city of Hamburg and its political institutions have made it possible to build HERA in Hamburg and that we can experiment in the middle of the city. That has a practicle and economic advantage; we can use the existing accelerators, for example PETRA, as injection machines, and therefore exploit to the full the investment which has already been made at DESY for the new apparatus. With HERA we will have in the next decade, as we have now, two high energy physics centres in Europe: CERN in Geneva and DESY in Hamburg which can undertake complementary research, as Prof. Panofsky has already described. So much for the future of elementary particle physics at DESY.

Let me briefly mention the future of our second important area, the synchrotron radiation work at the DORIS storage ring. Today DORIS is one of the best X-ray and synchrotron radiation sources in the world. We have an excellently equipped laboratory here, which is mainly used for X-ray physics. Since the opening of the Hamburg Synchrotron Radiation Laboratory in 1981, the number of users has reached several hundred scientists from Germany, predominantly from universities, and the demand for this valuable radiation source is steadily increasing.

DESY has now started a development program to improve the quality of radiation by the installation of so-called wiggler magnets and to increase the number of experimental areas, so that a good laboratory will also be available in the next decade. We are glad that our sponsors and financiers, the Federal

die mit der Synchrotronstrahlung arbeiten, und von den Hochenergiephysikern genutzt.

DESY feiert 25. Geburtstag und im allgemeinen freut man sich über Geburtstagsgeschenke an so einem Tag. Es scheint, daß die Natur uns eine Überraschung zum Geburstag beschert hat. Bei DORIS wurden im Crystal Ball-Detektor, der von Stanford nach Hamburg kam, um am DORIS-Speicherring gemeinsam von amerikanischen und europäischen Physikern betrieben zu werden, Anzeichen für ein sehr überraschendes Elementarteilchen gefunden, das etwa die achtfache Masse eines Wasserstoffatoms besitzt und dessen Existenz und Eigenschaften mit unseren bisherigen theoretischen Vorstellungen vom Aufbau der Natur nicht erklärbar erscheinen. Es ist sicherlich kein Teilchen, daß etwas mit Quarks oder Gluonen oder Leptonen zu tun hat, sondern etwas völlig anderes.

Wir müssen diese ersten Anzeichen noch sorgfältig prüfen, bevor wir sagen können, daß es wirklich eine Entdeckung ist. Und gegenwärtig arbeiten die Physiker bei DORIS daran, dieses Ergebnis, wenn möglich, zu erhärten. Sollte es sich bestätigen, dann ist es allerdings sehr aufregend, dann ist es eine echte Entdeckung, die uns einen wichtigen Schritt weiterbringen könnte in der Erkenntnis, wie die Natur im Innersten funktioniert. Vielleicht gelingt die Aufklärung bis zum richtigen Geburtstag am 18. Dezember.

Ich will nun am Ende meines Schlußwortes im Namen aller Mitarbeiter von DESY und aller Physiker und Wissenschaftler aus Deutschland und aus dem Ausland, die hier bei DESY arbeiten und forschen können, den Dank an die Stifter aussprechen für die Gründung von DESY und für die dauernde und vertrauensvolle Unterstützung unseres Laboratoriums über 25 Jahre hinweg und mit dem Wunsch schließen, daß unsere Arbeit bei DESY in den jetzt beginnenden 25 Jahren ebenso erfolgreich sein möge wie in der jetzt zu Ende gehenden Periode.

government and the Hamburg senate have agreed to an increase in our personnel, to make this development possible.

The long term future of synchrotron radiation depends on a number of factors. On the one hand it depends on whether and where a European X-ray source is built and on the other hand how much longer DORIS is demanded on its present scale for high energy physics. At the moment the machine runs jointly for synchrotron radiation and high energy experiments.

DESY celebrates its 25th birthday today and normally one looks forward to birthday presents on such a day. It appears that nature has prepared a surprise for us. At DORIS, the Crystal Ball detector, which came to DORIS from Stanford U.S.A. to be run jointly by American and European physicists, has seen indications for a very surprising elementary particle. It has about eight times the mass of a hydrogen atom and its existence and properties are not compatible with our present understanding of nature. It is certainly not a particle that has anything to do with normal quarks, gluons or leptons, rather something completely different.

We still have to check carefully these indications before it can definitely be said that it is a discovery. Physicists at DORIS are presently working on trying to strengthen the result. Should it be confirmed, it would be very exciting, because it is a discovery which could bring us a step further in our knowledge of how nature works. Perhaps an explanation will be available before our true birthday on 18th December.

At the end of my closing address, on behalf of all the staff at DESY, the physicists and scientists from Germany and abroad who can work and research here, I would like to thank the sponsors for founding DESY and for their continued and trusting support over the last 25 years. We hope that our work at DESY in the next 25 years will be just as successful as that in the last 25 years.

Am Rande gesehen

Seen from the Sidelines

Am Rande gesehen / *Seen from the Sidelines*

Foto DESY-PR Florian Becker

Foto DESY Jurgen Schmidt (37898/0)

Am Rande gesehen

Seen from the Sidelines

Foto DESY Jurgen Schmidt ([illegible])

Foto DESY Jurgen Schmidt (38346/1)

DESY Theorie-Workshop

Der schon zur Tradition gewordene DESY Theorie-Workshop fand in diesem Jahr während der Fest- und Informationswoche anläßlich des 25jährigen Jubiläums von DESY statt. Er wurde am Nachmittag des 24. Septembers mit einem wissenschaftlichen Kolloquium eingeleitet, auf dem in vier Vorträgen ein Rückblick auf die Elementarteilchenphysik und die Experimente mit der Synchrotronstrahlung gegeben wurde. M. Sands (Santa Cruz) sprach über "High Energy Machines - DESY and the World", H. Meyer (Wuppertal) über "High Energy Physics at the DESY Accelerators", H. Steinmann (München) über "Highlights in Synchrotron Radiation Research" und H. Fritzsch (München) über "Facts and Visions in Subnuclear Physics."

Schwerpunktthemen des Workshops waren schwache Wechselwirkungen von schweren Quarks, Erweiterungen des Standard-Modells, zum Beispiel das "Comopsite-Modell", Modelle der schwachen Wechselwirkung und ein Bericht über die Fortschritte bei Gittereichtheorien mit Fermionen. Das Organisations-Komitee (H. Fritzsch, F. Gutbrod, D. Haidt, H. Lehmann, D. Schildknecht) hatte 11 Vortragende eingeladen, zu diesen Gebieten über experimentelle und theoretische Ergebnisse und Vorstellungen zu referieren. Außerdem gab es Kurzvorträge, die interessante Anregungen brachten.

E. H. Thorndike (Rochester) berichtete über die neuesten Ergebnisse vom CESR Speicherring in Cornell. Die Messungen oberhalb des Y(4S)-Zustands zeigten Strukturen mit zwei neuen Resonanzen. Die Untersuchungen von semileptonischen Zerfällen der B-Mesonen liefern im Zusammenhang mit den gemessenen Lebensdauern wichtige Informationen über die Parameter der Kobayashi-Maskawa-Matrix.

DESY Theory Workshop

The traditional DESY Theory Workshop was held during the "Fest- und Informationswoche" which marked the 25th anniversary of DESY. It started with a scientific colloquium with four review talks on the history of elementary particle physics and experiments with synchrotron radiation in the afternoon of September 24th. The lecturers were M. Sands (Santa Cruz) on "High Energy Machines - DESY and the World", H. Meyer (Wuppertal) on "High Energy Physics at the DESY Accelerators", H. Steinmann (München) on "Highlights in Synchrotron Radiation Research" and H. Fritzsch (München) on "Facts and Visions in Subnuclear Physics".

The workshop concentrated on weak interactions of heavy quarks, on non-standard, e.g. composite models for weak interactions, together with a progress report on lattice gauge theories with fermions. The organizing committee (H. Fritzsch, F. Gutbrod, D. Haidt, H. Lehmann, D. Schildknecht) had invited eleven lecturers to present experimental and theoretical ideas in these fields. Short communications also contributed interesting material.

E. H. Thorndike (Rochester) reported on recent results from the CESR storage ring at Cornell. The energy scan in the region above the Y(4S)-state showed structures with two new resonances. The study of semileptonic decays of B-mesons, when combined with the B-lifetime results, leads to important information on the parameters of the Kobayashi-Maskawa matrix.

K. Hayes (SLAC) explained the art of extracting the tiny offset of the decay vertex of heavy mesons produced in electron-positron annihilations. It was gratifying to see how consistently five experiments came up with a B-lifetime of around one picosecond.

Foto DESY Jürgen Schmidt (37900/9)

W. Paul M. Sands

K. Hayes (SLAC) beschrieb die Kunst, den winzigen Abstand des Zerfallsspunktes von schweren Mesonen zu bestimmen, die in Elektron-Positron-Vernichtung erzeugten wurden. Erfreulicherweise konnten fünf Experimente die Lebensdauer des B-Mesons übereinstimmmend zu etwa einer Pikosekunde angeben.

C. Jarlskog (Bergen/Stockholm) gab einen umfassenden Überblick zum gegenwärtigen Stand des "family mixings". Die Art des Quark-Mixings konnte ziemlich eng eingegrenzt werden. Während die Mischung der ersten und der zweiten Generation durch den Sinus des Cabibbo-Winkels (= 0,23) gegeben ist, ist die Mischung der zweiten und dritten von der Größenordnung seines Quadrates und die der ersten und dritten Generation höchstens so groß wie seine dritte Potenz.

Die schwachen Zerfälle sind ein wertvolles Filter für schwere Quarks in Elektron-Positron-Jets, besonders wenn diverse Jet-Parameter im Zusammenhang untersucht werden. Wie R. Marshall (Rutherford Lab.) darlegte, hat sich für die Fragmentation schwerer Quarks ein einheitliches Bild ergeben. Die Axialladung des b-Quarks kann sehr gut durch die asymmetrische Winkelverteilung bezüglich der Strahlrichtung gemessen werden. Sie stimmt mit den Vorhersagen des Standard-Modells überein.

Foto DESY Jürgen Schmidt (37900/5)

K. Johnsen S.C.C. Ting W.K.H. Panofsky

C. Jarlskog (Bergen/Stockholm) gave a comprehensive review of our present knowledge on the question of family mixing. The pattern of quark mixing has been pinned down tightly. While the mixing of the first and second family is given by the sine of the Cabibbo angle (= .23), the mixing between the second and third family is of the order of its square and the mixing between the first and the third generation is at most of the order of its cube.

The weak decays provide a valuable filter for heavy quarks in electron-positron jets, especially when several jet variables are analysed in conjunction. As R. Marshall (Rutherford Lab.) showed, a consistent picture for heavy quark fragmentation has emerged. The axial charge of the b-quark can be well measured due to the asymmetric angular distribution with respect to the beam axis. It agrees with the standard model predictions.

The ARGUS-Collaboration, working at DORIS II was represented by J. Stiewe (Heidelberg). He showed, among many other results, evidence for the F at a mass of 2114 MeV. Also five good candidates for antideuterons have been observed, the rate being qualitatively in accordance with thermodynamic expectations.*

Foto DESY Jurgen Schmidt (37911/4)

E. Lohrmann P. Dalitz

Für die ARGUS-Kollaboration, die an DORIS II arbeitet, berichtete J. Stiewe (Heidelberg). Neben vielen anderen Resultaten zeigte er Hinweise für das F* bei einer Masse von 2114 MeV. Außerdem wurden fünf sichere Kandidaten für Antideuteronen beobachtet, deren Erzeugungsrate qualitativ mit den thermodynamischen Erwartungen übereinstimmt.

B. Stech (Heidelberg) widmete den größten Teil seines Vortrags den schwachen Zerfällen von schweren Mesonen. Er stützte sich auf eine effektive Hamilton-Funktion, die die Mehrzahl der nichtleptonischen Zwei-Körper-Zerfälle erfolgreich beschreibt.

S. Nussinov (Tel-Aviv) trug verschiedene Methoden zur Herleitung von Massen-Ungleichungen vor. Zum Beispiel veranlaßt durch potential-ähnliche Modelle hat man viele Massen-Ungleichungen in der Gitter-QCD erhalten (sowohl im Hamiltonschen als auch im Euklidischen Formalismus).

Obwohl das Standard-Modell für die elektroschwache Wechselwirkung anscheinend ausgezeichnet funktioniert, gibt es gute Gründe, es zu erweitern, wie D. Schildknecht (Bielefeld) erklärte. Eine Möglichkeit besteht darin, die W- und Z-Bosonen als zusammengesetzt anzunehmen, was dann zu Abweichungen vom Standard-Modell führen würde. Dadurch erhält man

Foto DESY Jurgen Schmidt (37911/8)

J. von Krogh G. Heinzelmann J. Heintze

B. Stech (Heidelberg) devoted the main part of his talk to weak decays of heavy mesons. He worked with an effective Hamiltonian which successfully describes the bulk of non-leptonic two-body decay data.

S. Nussinov (Tel-Aviv) reviewed various methods to derive mass inequalities. Partially motivated by potential-like models, many mass inequalities have been obtained in lattice QCD (both in its Hamiltonian and Euclidean formulation).

Although the standard electroweak model seems to work beautifully, there are good reasons to go beyond it, as D. Schildknecht (Bielefeld) emphasized. One way of is to consider W's and Z's as composites, which leads to departures from the standard model. These ideas predict a rich spectrum of heavy particles in the 200 GeV range, and consequently many unusual events in collider physics.

J. Kogut (Urbana) reported on the attempts to put fermions on the lattice. There are still the limitations posed by the No-Go theorem in connection with species doubling and chiral symmetry. But progress has been made in understanding the nature of the finite temperature deconfining transition which also restores chiral symmetry.

Vorhersagen für ein umfangreiches Spektrum an schweren Teilchen im Bereich von 200 GeV und folglich eine Reihe von ungewöhnlichen Ereignissen an Collider-Experimenten.

J. Kogut (Urbana) berichtete über die Bemühungen, Gittereichtheorien für Fermionen zu formulieren. Dabei sind noch die Probleme zu klären, die vom No-Go-Theorem bezüglich der Artenverdopplung (species doubling) und chiralen Symmetrie aufgeworfen werden. Aber es wurden Fortschritte gemacht im Verstädnis der Natur des Deconfinement-Phasenübergangs bei endlicher Temperatur, der gleichzeitig die chirale Symmetrie wieder herstellt.

Von T. Walsh (Minnesota) wurden zum Thema "Exotische Teilchen" (unterhalb 1 TeV) einige unerwartete experimentelle Entdeckungen vorgestellt, speziell elektromagnetische Zerfälle des Z0, anomale Jets bei Proton-Antiproton-Vernichtung und das CELLO-Ereignis. Die theoretischen Versuche, diese Ereignisse zu interpretieren, basieren auf Compositness und Supersymmetrie.

Im abschließenden Vortrag beschrieb M. Peskin (SLAC) die augenblicklichen Konzepte bei der Suche nach dem Higgs-Teilchen. Diverse Überlegungen führen zu Grenzen oder Bereichen für seine Masse, und so muß man auch mehrere Möglichkeiten bei der experimentellen Suche berücksichtigen. Es hat sich herausgestellt, daß das (später nicht bestätigte) Zeta(8320)-Teilchen nicht so leicht an die Vorhersagen für ein Higgs-Teilchen angepaßt werden kann. Wahrscheinlich muß man noch eine Weile auf die Entdeckung des Higgs-Teilchens warten, das eine zentrale Rolle bei der Erzeugung von Massen spielt.

Frau H. Laudien und Frau I. Schwartz haben viel zu der angenehmen Atmosphäre des Workshops beigetragen und waren für die Teilnehmer und Organisatoren eine wertvolle Hilfe.

F. Gutbrod/H. Lehmann

Foto DESY Jurgen Schmidt (37911/17)

Several unexpected experimental findings were presented by T. Walsh (Minnesota) in his talk on "Exotic Particles" (with masses below 1 TeV), in particular radiative Z0 decays, anomalous jets from the proton-antiproton collider and the CELLO event. Theoretical attempts to interpret these events are based on compositeness or supersymmetry.

In the concluding lecture M. Peskin (SLAC) explained the present concepts how to pursue the Higgs particle. Several ideas give limits or suggest ranges for its mass, and correspondingly one has to consider many options for the experimental search. It became clear that the (no longer healthy) Zeta(8320) particle did not fit easily into the expectations for a Higgs particle. Perhaps we will have to wait a bit longer for the discovery of the Higgs particle, with its central rôle for mass generation.

Mrs. H. Laudien and Mrs. I. Schwartz provided most valuable help to the participants and organizers and contributed to the pleasant atmosphere of the workshop.

F. Gutbrod/H. Lehmann

Viel Spaß bei der internen Geburtstagsfeier

Das DESY-Betriebsfest fand ebenfalls in der Jubiläumswoche statt und gestaltete sich zu einer echten Geburtstagsparty. Unter der Leitung von Rolf Pamperin und Hannelore Grabe stellte das Festkomitee für die DESY-Mitarbeiter, ihre Familien und Freunde ein buntes Programm zusammen, bei dem Spiel, Spaß und Unterhaltung groß geschrieben waren. Viele der Darbietungen wurden von "hauseigenen" Künstlern arrangiert, zum Beispiel die Pantomime, das Zaubern, Kabarett, Tanz- und Disco-Musik.

Der Erlös dieses Festes sollte für einen guten Zweck gespendet werden; er wurde zu einem großen Teil während einer Sammelaktion erzielt, tatkräftig unterstützt von einer Drehorgel. Am Ende konnten einer Behinderten-Sonderschule in der Nachbarschaft 4420 DM überreicht werden.

Lots of Fun at the Internal Birthday Party

The DESY Works Festival was also held in the jubilee week - it turned out to a real birthday party! Under the chair of Rolf Pamperin and Hannelore Grabe the festival committee arranged a colourful programm for the DESYaner, their families and friends with a variety of games, fun, and entertainment. Many of the presentations were done by DESY artists, e.g. the mime show, the magic show, the cabaret, the dancing and disco-music.

The proceeds of the festival were intended to be contributed to a charitable cause. The money was mainly given during a collection vigorously supported by a barrel-organ. Finally an amount of 4420 DM could be donated to a School for Disabled Persons in the DESY neighbourhood.

Foto DESY Manfred Klinkmuller

Fotos DESY Manfred Klinkmüller

Fotos DESY Manfred Klinkmüller

Fotos [illegible] Becker

Großes Interesse an DESY

Es kann nicht nur am schönen Wetter gelegen haben, daß der letzte Tag der Fest- und Informationswoche auf solches Interesse gestoßen ist. Knapp 10.000 Besucher kamen zu DESY, um sich vor Ort über die Hochenergiephysik im allgemeinen und die DESY-Beschleuniger und -Experimente zu informieren.

Stündliche Einführungsvorträge bereiteten die Besucher auf die drei Rundkurse vor, von denen der längste zwei Stunden dauerte. Die Fußmüden hatten Gelegenheit, in die Elektrobahn oder in Busse zu steigen. Neben den Hauptanlaufstellen (Beschleuniger-Kontrollraum und -Tunnel, Hochenergieexperimente und HASYLAB) stießen aber auch die Abstecher zum Rechenzentrum, den Werkstätten, Speziallabors und zur HERA-Baustelle West auf großes Interesse.

Great Interest in DESY

Nearly 10,000 came to visit DESY on the last day of the "Fest- und Informationswoche". They were not only attracted by the wonderful weather, but showed special interest in learning about high energy physics in general and the DESY accelerators and experiments.

Introductory talks were held every hour to prepare the visitors for the three circular tours, the longest of which took two hours. An electric train and busses transported those who were tired.

Main points of the tours were the accelerator control room and tunnels, the high energy experiments and HASYLAB, but the visitors showed the same great interest in the computer centre, the workshops, the special laboratories and the HERA West building site.

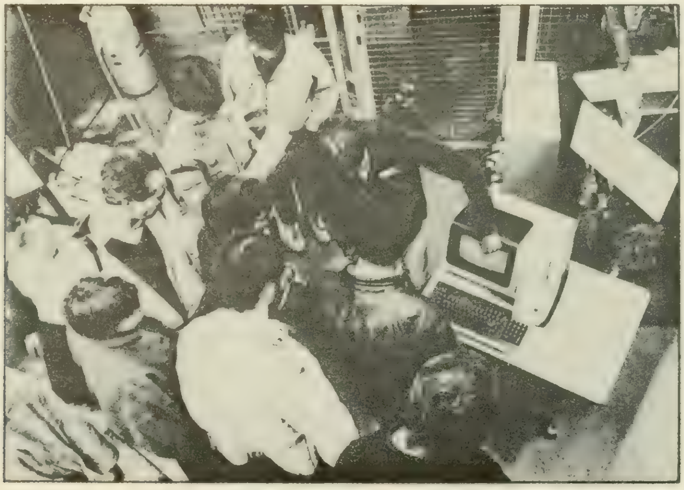
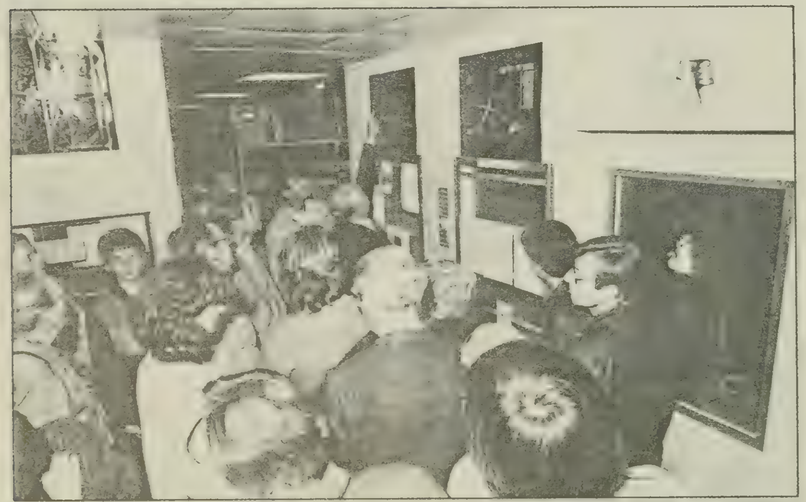


Foto DESY-PR Florian Becker

Fotos DESY-PR Florian Becker



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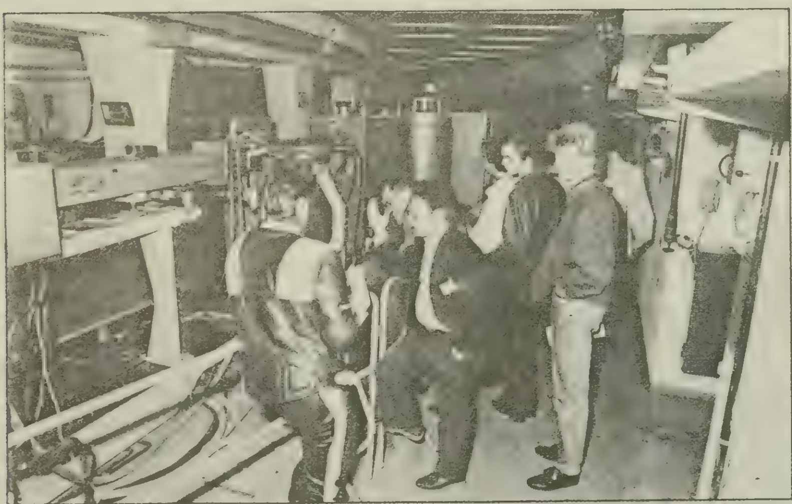

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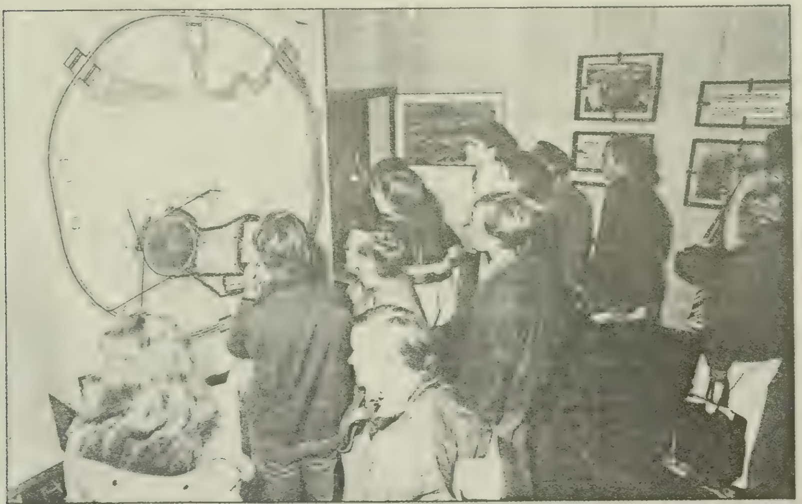

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Foto DESY-PR Florian Becker

DESY JOURNAL

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Foto DESY Jürgen Schmidt (37911/25)

Gemeinsam mit Willibald Jentschke und Volker Soergel feiern 34 DESYaner ihr persönliches 25jähriges DESY-Jubiläum, wobei Erinnerungen an die Anfänge ausgetauscht wurden. Besonders deutlich hatten einige noch ihren ersten Arbeitsplatz vor Augen: eine Dachgeschoßwohnung im physikalischen Institut der Hamburger Universität mit Blick auf den Innenhof des Untersuchungsgefängnisses.

Together with Willibald Jentschke and Volker Soergel 34 DESYaner celebrated their personal 25th DESY-anniversary. They exchanged reminiscences on the beginning of DESY and a few of them could still remember very well their first offices in an attic in the Physics Institute of the University of Hamburg with a view into the inner courtyard of the prison.


HERA
Deutsches Elektronen-Synchrotron DESY Hamburg
English
DESY

HERA - A Super-Electron Microscope for Studying the Smallest Building Blocks of Matter

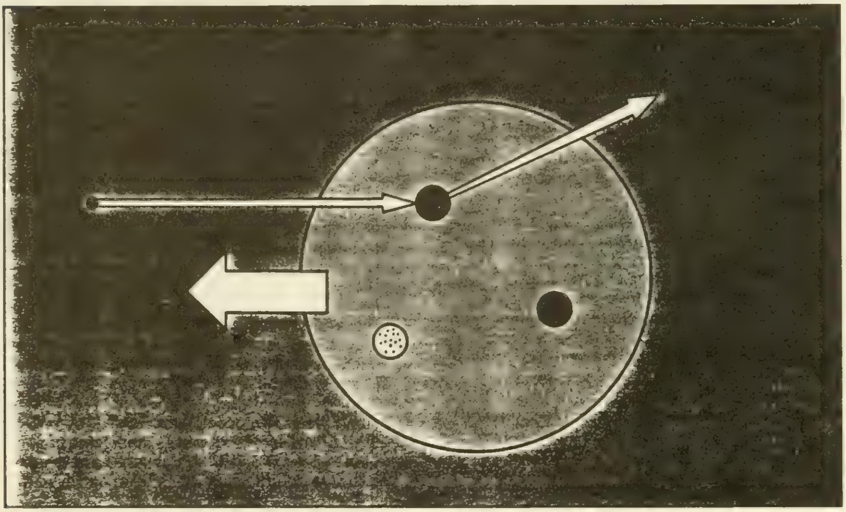
From 1984 to 1989 the Hadron-Electron-Ring-Accelerator HERA, a large instrument for fundamental reserarch is to be built at the Deutsches Elektronen-Synchrotron DESY in Hamburg. With HERA research into the smallest structures of the microscopic world will take a decisive step forward.

In HERA, electrons and the 2000 times heavier protons will circulate in a vacuum in two separate "storage rings" mounted on top of each other in a 6.3 kilometre underground tunnel. The particles travel in opposite directions at almost the speed of light, guided by magnetic fields. They are allowed to collide with each other in four separate interaction points. The collisions are observed in complex "detectors". Accurate measurements of these processes will provide information on the smallest structures of matter down to dimensions of 0.000 000 000 000 000 1 millimetres.

A great deal of advanced technology is needed to build HERA. This includes superconducting magnets for the proton ring, large cryogenic installations for liquid helium, ultra-high vacuum systems, high power radio frequency equipment and an advanced computer network for controlling the whole system.

HERA will be built with international participation. The foreign partners will supply components which they will develop and build in their own countries. Continuing in what is a tradition at DESY, scientists from all over the world will be able to work on HERA.

HERA will be the first, and probably for many years the only electron-proton storage ring in the world. This puts DESY into a unique position as a leading laboratory for the study of the structure of matter.



The Mystery of Matter

Man has only a very restricted view of the world in which he lives due to the limited ability of the eye to resolve either small or far away objects. However, this obstacle does not exist for his mind and for many centuries he has tried to overcome his natural limitations with technical aids in order to gain insight into the macro- and microsomic world.

The first technical aids were glass lenses, from which first the telescope and then the microscope were developed. Exciting discoveries in astronomy were made which led to a deeper knowledge of our world. They also created a strong demand for better and better telescopes. The latest developments in this venture are the large radio telescopes and various instruments born by satellites to observe distant objects in space.

No less exciting has been the step by step unravelling of the world of the small, eventually down to exploring the nature of matter itself. With the miroscope it was possible to see that matter was made of smaller structures: for example, a living organism is made of single cells. About 100 years ago the next stage was reached: matter was found to be made of molecules which in turn are made of atoms. The tremendous variety in which matter appears was thereby reduced to less than 100 different types of atoms: the chemical elements.

At the beginning of this century it was recognized that atoms were not the indivisible elementary particles they were originally thought to be. Instead, they are like miniature planetary systems with a positively charged nucleus at the centre and negatively charged electrons circulating around it. The nuclei, which contain almost all the mass of the atoms, are in turn made from other particles, the protons and the neutrons. Atoms can therefore be described as being made of three "elementary" constituents, the proton, the neutron and the electron.

Are these particles correctly termed "elementary"? In studies of the radiation coming from the sun and from space, and since the fifties also in experiments at accelerators, many new short-lived particles were discovered which merit the term "elementary" equally well. They are related to the nuclear constituents and with them, form the family of "hadrons". Relatives of the electron were also found which together with the electron, form the family of "leptons".

Given this multitude of different particles one began to suspect that they were not really the ultimate elementary building blocks of matter. Experiments with very energetic electrons from accelerators (for example the DESY synchrotron) enabled the inner structure of the proton to be "illuminated". Further research, for example on the storage rings DORIS and PETRA at DESY, showed that the hadrons are made of substractures named quarks. The proton and the neutron are each made of three quarks. However, the electron shows no structure, it still appears to be pointlike and elementary.

According to our present understanding there are six kinds of leptons and six kinds of quarks. Five of the quarks have so far been discovered and the sixth is being searched for at the large accelerators. All the matter around us, is composed of only two varieties of quarks, the "d" and the "u", together with the electron. The other quarks and leptons played an important role in the creation of matter. In the early stages of the universe they were transformed into the forms of matter we now see.

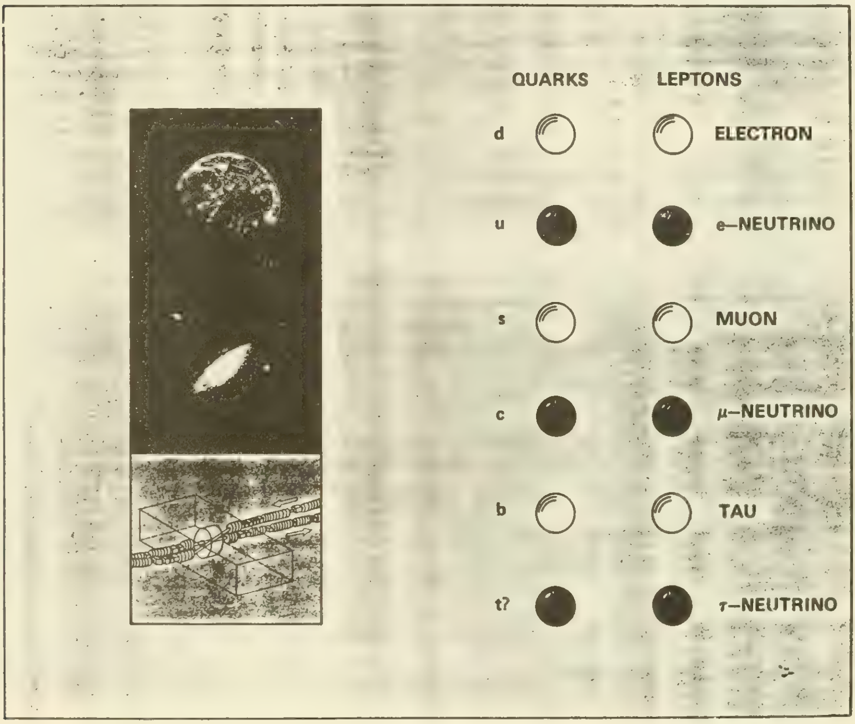
Are these quarks and leptons really the ultimate indivisible building blocks of matter? Why then are there just two times six kinds of particles? Many physicists doubt that the secrets of matter have really been unravelled as long as no statisfactory explanation for this scheme has been found. They suspect that at a deeper level, true "elementary" particles exist which combine to make the quarks and leptons. The quarks and leptons would then be expected to have structure, and not to be pointlike as they appear to be at the present level of experimental precision. Accelerators of a new generation are therefore planned in many parts of the world, in order to research into these and many other open questions on the nature of matter, of which only a few could be touched upon here.

Among these new accelerators are HERA in Hamburg, LEP in Geneva, as well as other large projects in the U.S.A., U.S.S.R. and Japan. As a result of worldwide coordination it has been achieved that

each of these large installations is optimized for a particular kind of research, avoiding duplication of effort and cost.

HERA in this context, has the particularly interesting task of becoming an electron microscope for the quarks.

Apart from those kinds of quarks and leptons which make up stable matter there are additional types, some of which occur in the cosmic radiation. They have played an important role in the creaction of matter. They transformed into the known forms of matter in the early stages of the universe. It has been possible to re-create them (with the exception of the t quark) with particle accelerators.



HERA - A Super-Microscope

HERA will open a new dimension in the search into the nature of matter. Questions like
- How elementary are the quarks?
- Do they have an inner structure?
- Which principles has nature used to build the quarks?

can be investigated with HERA.

The power of HERA can best be illustrated by a comparison: To the naked eye the planet Mars appears as an bright point in the night sky. With the telescope it was possible to oberserve its shape.

Modern instruments reveal in increasing detail what it looks like on Mars. If one had an instrument for planetary observation that is as powerful as HERA will be for the microcosm, then pointing it to Mars one could detect objects of microscopic size on its surface!

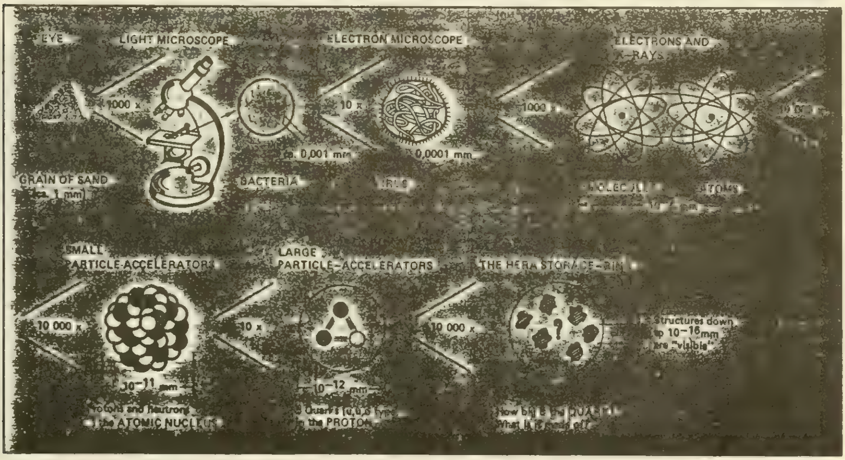
How does a super-microscope like HERA work? For every microscope the size of the smallest object which can be seen or "resolved", is determined by the fineness of the probe which illuminates the object. For a normal microscope the probe is visible light and its wavelength of about 0.000 5 millimetres fixes the limit of the resolution. For finer probes one turns to X-rays or energetic electrons which are used for example in the electron microscope. With these probes one can resolve details up to 10 000 times smaller than that visible by light.

X-rays or electron beams are more energetic than light. In general, the higher the energy of the probe the finer the structure one can resolve.

In order to study the interior of protons, HERA uses electrons which are accelerated to a very high energy of 30 GeV (30 billion electron volts). In this way, one is able to resolve structures down to 0.000 000 000 000 000 1 millimetres, one ten thousandth of the diameter of a proton, or one billionth of the diameter of a hydrogen atom. In order to fully exploit the energy of the electrons in probing the protons, they are met by protons flying in the opposite direction, at an energy of 820 GeV.

The protons are made of three quarks, and these

From a grain of sand to the quarks: Steps in exploring the structure of our world.

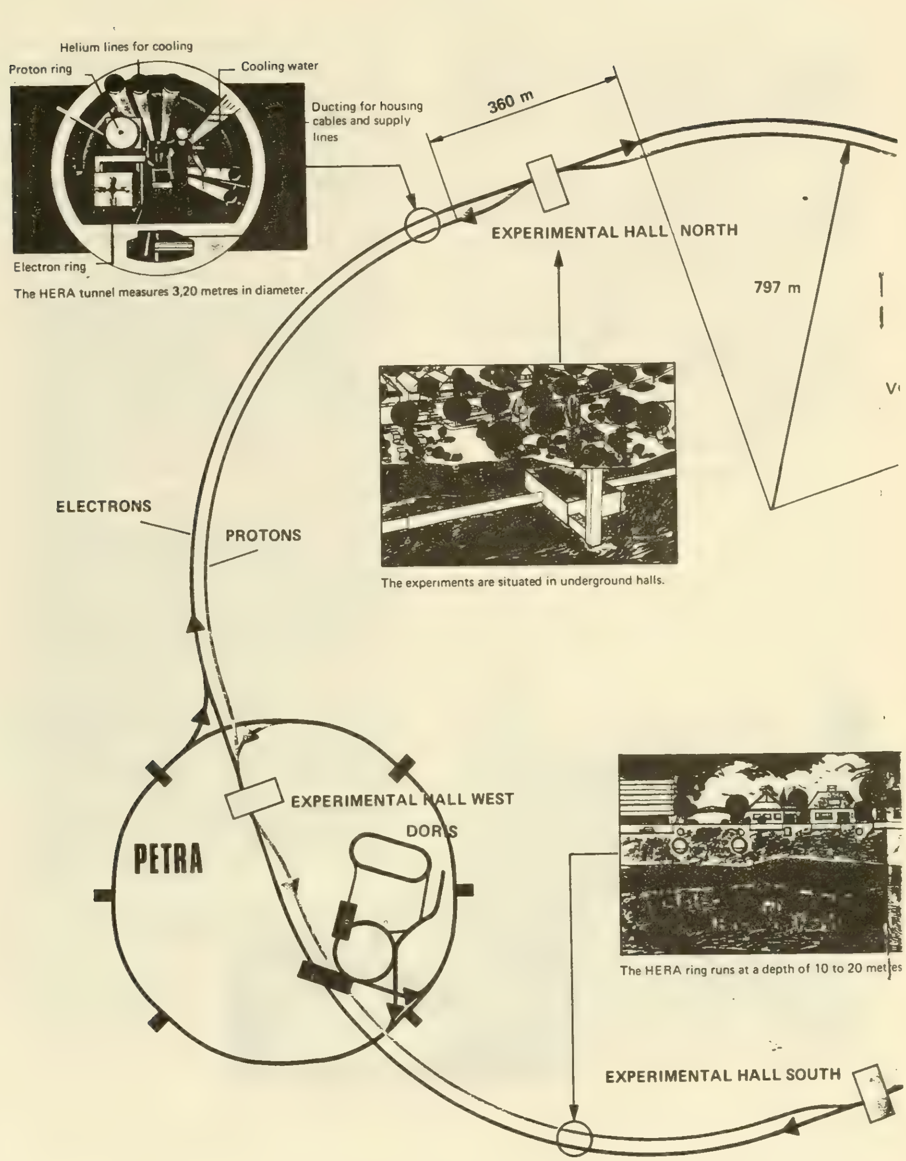


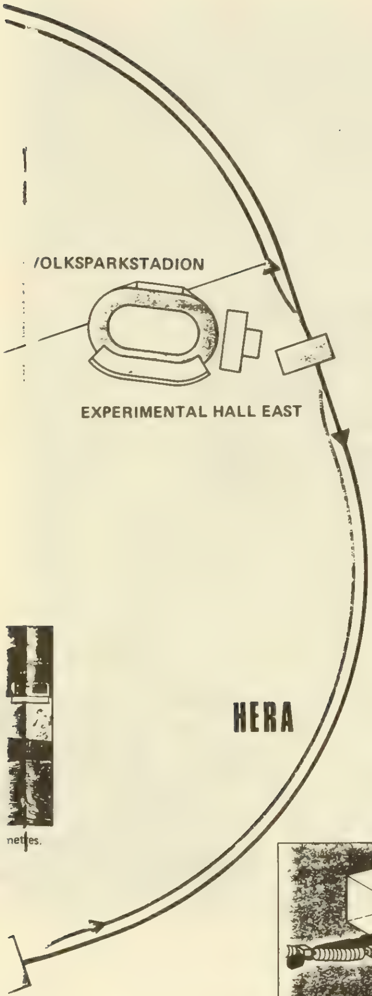
are the objects that one really wants to study at HERA. It has not been possible to produce single quarks on their own, but the electrons will penetrate into the proton and expose the quarks. At a later date other atomic nuclei which have different combinations of quarks may also be studied. Thus, HERA is a super-electron microscope for studying quarks.

The high energy accelerators in the 1980's and 1990's

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DESY (Hamburg)	HERA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FNAL (Chicago)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IHEP (Serpukov)	UNK	[illegible]	[illegible] 990	[illegible]	[illegible]	[illegible]
CERN (Geneva)	SPS LEP	[illegible] 27.0 km	[illegible] [illegible]	[illegible]	[illegible]	[illegible]
SLAC (Stanford)	SLC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
KEK (Tokyo)	TRISTAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]


HERA
PETRA


Helium lines for cooling
Proton ring
Cooling water
Ducting for housing cables and supply lines
Electron ring
The HERA tunnel measures 3,20 metres in diameter.
360 m
EXPERIMENTAL HALL NORTH
797 m
ELECTRONS
PROTONS
The experiments are situated in underground halls.
EXPERIMENTAL HALL WEST
DORIS
PETRA
The HERA ring runs at a depth of 10 to 20 metres
EXPERIMENTAL HALL SOUTH



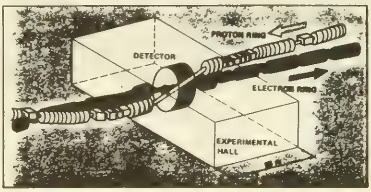
netes.

HERA - A Storage Ring

In HERA, tightly packed bunches of some 100 billion electrons and protons will cross each other. Occasionally an electron will collide with a proton; however, because of the tiny dimensions of the particles this does not occur very often. Therefore the particle bunches pass through one another without any large disturbance. Using a trick it is possible to collide the same bunches about one billion times with each other and so increase the number of collisions: They are guided round a ring by magnetic fields and keep returning to the same point where they meet again and again. In HERA the particles will circulate 50 000 times a second. They are held in an orbit in the ring, and therefore such an apparatus is called a "storage ring". The collisions of the stored particles are observed and measured. After a few hours the storage rings must be refilled with particles, a process which will take about half an hour.

Already in the past, storage rings have played a crucial role in studying the structure of matter. The investigation of electron-positron collisions in storage rings has proved very fruitful (positrons are the positively charged antiparticles of the electrons). PETRA at DESY is at present the largest (2.3 km circumference) and most powerful electron-positron storage ring in the world. The discoveries at PETRA have made a significant contribution to our present level of understanding the structure of matter. A much larger machine of this type, LEP (Large Electron-Positron Project), is now being built at the European Research Centre, CERN. At CERN there is also a pròton-antiproton storage ring, at which the heavy bosons W and Z° were discovered in 1983.

Owing to the different masses of the two types of stored particles in HERA (the proton is 2000 times havier than the electron), two separate rings are necessary which differ in construction. Therefore



The electron and proton beams cross at four interaction regions

HERA consists of two storage rings in which the electron and proton bunches travel in opposite directions. The rings are mounted one above the other in a 6.3 km long underground tunnel. They cross at four interaction regions where the electron and proton bunches collide. Large detectors to register the collisions surround the interaction points. At these points the tunnel is enlarged into underground halls.

The most important components of the HERA storage rings are:

- The magnet system. This consists of bending magnets which guide the particles on their orbit, and of focussing magnets which direct stray particles back to the centre of the vacuum pipe.
  Each of the rings has about 1000 electromagnets. In order to reach the required magnetic field strength the coils of the magnets for the proton ring are made of superconducting material.

- The vacuum pipes in which the particles travel. They must be evacuated to ultra-high vacuum to give the particles a free path with the fewest possible collisions with gas molecules. The particle bunches will be stored in the rings for many hours and in that time travel about a hundred times the distance from the earth to the sun. Collisons with gas molecules on this long path, which throw the particles from their orbit, must be minimized in order to keep this loss as low as possible. Therefore the ultrahigh vacuum is essential.

- The high frequency accelerating system. This has to accelerate the particles up to high energies after injection into the storage ring.
  The high frequency system must also continually supply energy to the stored electrons to compensate for the losses due to the so-called synchrotron light which they radiate during the bending in the magnets.
  Owing to the greater proton mass synchrotron light is no problem with protons.

- The control system. This comprises a large number of electronic measuring devices and computers.

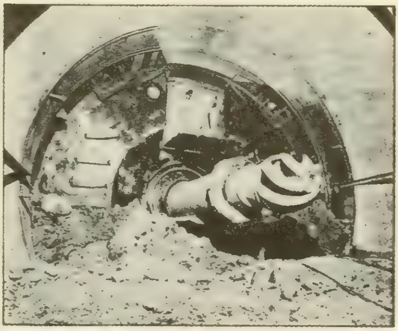
- The injection system for pre-accelerating the electrons and protons before they can be injected into the HERA rings.

All the present DESY accelerators with the exception of DORIS, will be needed for pre-acceleration and injection. In addition, a proton linear accelerator must be built and PETRA must be modified to serve as a pre-accelerator for electrons and protons.

DESY's smaller electron-proton storage ring, DORIS, will continue to be used after the completion of HERA for special studies in electron-positron physics and as a synchrotron radiation source for atomic, molecular and solid state physics and also for medical and biological research.

With the running of HERA the amount of electricity used annually at DESY will only increase slightly: A yearly consumption of about 250 millions kilowatt hours is expected with HERA operating for 5000 hours. For comparison, 221 million kilowatt hours were used in 1983.

A special boring machine equipped with a driving shield



Construction and Operation of HERA will not Affect the Environment

The HERA tunnel will be 10 to 20 metres below the earth's surface. Four-fifths of it are outside the DESY site, mostly under state-owned large green areas (the Hamburg Volkspark). Three of the four experimental halls are also outside DESY.

Test bores have shown that the tunnel will lie in a large sand basin and half of it will be under the water table. The tunnel will be drilled using a special boring machine equipped with a driving shield, a method extensively used in Hamburg which causes no problems in sand. The tunnel's route crosses partly under developed areas, including private homes. At a depth of more than 15 metres, however, damage to buildings can be practically ruled out.

The only structures for which excavation will have to be done, are the four multi-story underground halls, 42 metres long and 25 metres wide. After their completion only small entrance buildings will be visible on the surface and with suitable styling and landscaping they will hardly be noticeable. The only evidence of HERA outside DESY will be these entrance buildings and a survey tower.

The construction work will start with the excavation of one of the halls. After that the tunnel will be bored. For the construction the Hamburg civil engineering authority has taken the responsibility.

Does HERA produce dangerous radiation? As long as the electrons and protons are travelling in the beam pipes no radiation at all is leaving the tunnel. Only those few particles which happen to leave their orbit and hit walls of the vacuum pipe can produce penetrating radiation. As the tunnel is between 10 and 20 metres below the earth's surface the escaping radiation is greatly reduced through the shielding by the overlaying material.

How large is the radiation dose on the surface due to the operation of HERA? To answer this question the electrons and protons must be considered separately.

The radiation from the electrons is so effectively shielded by the material above the tunnel that the operation of the electron ring will not increase the radiation level beyond that already present from the earth and from cosmic rays by more than one part in a thousand. This assertion is based on measurements with high energy electron beams at the DESY synchrotron and other electron accelerators as well as at the PETRA storage ring, where high energy electrons are also stored, i.e. where similar conditions occur as in HERA.

The radiation from the protons depends on the depth of the tunnel below the surface, but it is everywhere less than 3 % of the natural radiation level. Quantitatively: the average natural radiation level in Hamburg is 100 millirems per year and a maximum of 3 millirems per year can come from HERA. In the regions where the tunnel runs under residential areas the radiation level at the earth's surface is less than 1 millirem per year, i.e. less than one hundredth of the natural radiation in Hamburg. This information comes from measurements at the European Research Centre, CERN, in Geneva.

The operation of HERA therefore will produce only very little radiation, negligible compared to the natural radiation level.

What will happen in case of a breakdown or an emergency? All the stored particles will then be immediately lost. The electrons hit the wall of the beam pipe but due to the thickness of soil no detectable radiation can emerge to the surface. The protons will run into a special radiation absorber which is shielded so well that the radiation emerging at the surface is not stronger than during normal operation. After the loss of the particles HERA is empty and will produce no more radiation.

A storage ring like HERA can therefore without any risk be operated in an inhabited area.

Research with HERA

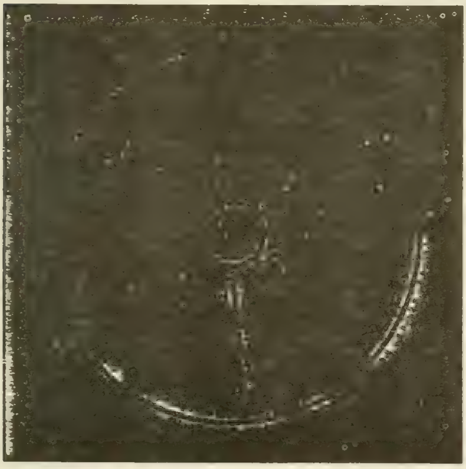
HERA will have four interaction points at which the electron-proton collisions will be registered and precisely measured with the help of large detectors. At DESY's electron-positron storage ring PETRA four large detectors are operating which can give an idea of the size and complexity of these installations.

The conditions under which the particles collide and under which one detects their collisions have to be modified in many ways when one wants to investigate the properties and behaviour of the smallest particles. One talks therefore of experiments which are carried out using the detectors. These detectors will be built and operated by international collaborations, as successfully demonstrated at PETRA. Scientists from many different countries will work together on the design, construction and running of the experiments.

At present, research groups from 14 German universities and research institutes and from 32 foreign scientific institutions from four continents are working on high energy experiments at the PETRA and DORIS storage rings. This international collaboration will be continued and probably expanded at HERA.

Each storage ring experiment sets out to answer a number of scientific questions. Many young scientists take this unique opportunity to do their Ph.D. thesis research at the very frontiers of their field; about 200 of them, from many different countries, are presently working on the PETRA and DORIS experiments.

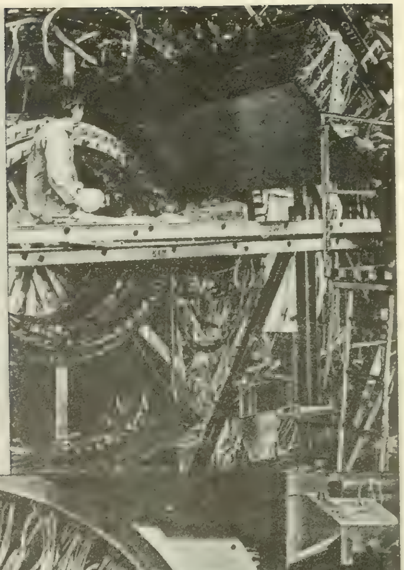
The high energy physics experiments are a particularly good example for an active collaboration between university professors and students for the teaching through collaboration in research. Thus HERA will provide the next generation of scientists the possibility to continue with the fascinating research into the microcosmic world. In 1990, when the experiments at HERA will begin, the students who enter the universities in 1984 will just begin their post graduate research!

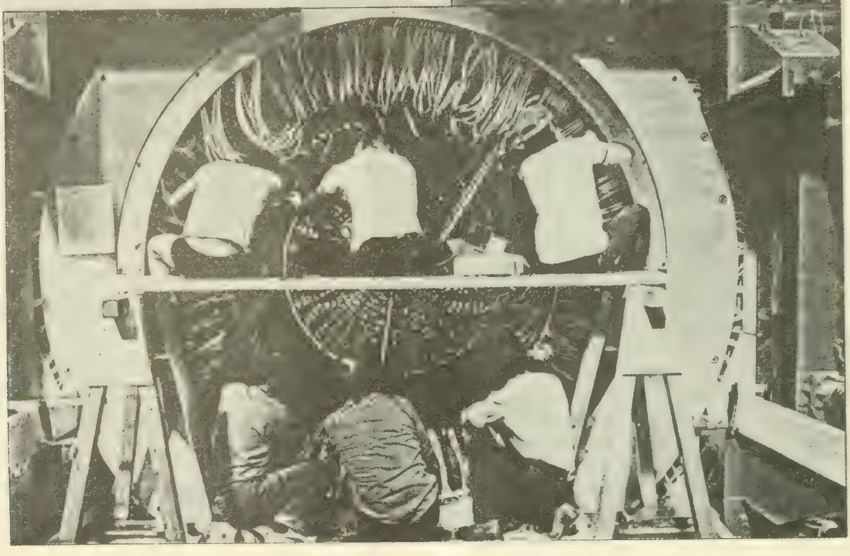


A "physical" event. Evidence for a quark, antiquark and gluon in a detector at the storage ring PETRA at DESY. The gluon is the "glue" that holds the quarks together in matter, and which has been made "visible" at PETRA. The picture shows the reconstructed trajectories of single hadrons which were created by the fragmentation of the three tiny particles. The quark, antiquark and gluon in turn were created from the (invisible) collision of an electron and a positron in the middle of the picture. From exact measurements of the three "jets" the direction and speed of the quark, antiquark and gluon during their 10^{-13} mm flight path can be reconstructed. Similar pictures will also be produced by the detectors at HERA.

Picture right: Assembly of a detector at PETRA. One of the complicated pieces of equipment is being installed in the detector. It enables evidence for particular decays of quarks to be obtained.

Picture below: A Korean Ph.D. student from the U.S.A., a laboratory assistent from Hamburg, an Indonesian engineer, a physics professor from Moscow, a German enigneer and a German technician working together during the cabling of the 5940 signal wires at one of the detectors at DORIS





HERA - Operational in 1990

Plans for an electron-proton storage ring have already been discussed at DESY at the beginning of the 1970's. In 1979 the main parameters for HERA were fixed in a joint study from DESY and ECFA, the European Committee for Future Accelerators. A technical proposal for HERA has been worked out on this basis by a colloboration of 50 physicists and accelerator specialists from many countries in 1981.

To assess the various large projects for basic research in the 1980's, the Federal Minister for Research and Technology called a special committee. It reported in spring 1981 and recommended that in principle, HERA should be built. In December 1983 the committee recommended to begin with the construction of HERA in the near future. With its original recommendation the committee proposed that in view of the large investment of 654 million DM (at 31st December 1980 prices) and the use of the machine by physicists from all over the world, HERA should be built in international collaboration with contributions from other countries.

After thorough discussions and negotiations, various laboratories and research organisations in Canada, France, Great Britain, Holland, Israel and Italy have declared that they are prepared to make significant contributions in form of components to be developed and built by the participating institutes in collaboration with industry.

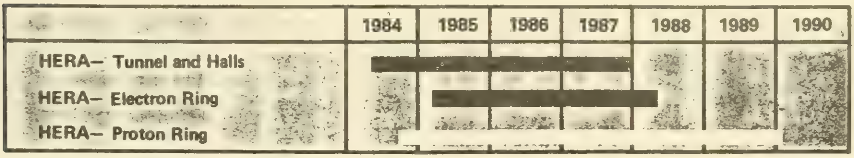
Such a collaborative building of a large accelerator at a national research centre is without precedence. The willingness of the foreign partners to participate in the building of the accelerator once more demonstrates the high expectations the physics world has for HERA.

Industry in Germany and the other participating countries expect that their involvement in high technology work for HERA will give them an important boost to their technical capability. This is particularly true for the areas of superconductivity, cryogenics, radio frequency- and control systems as well as the large diversity of electrical supply equipment. Experience from the building of PETRA has shown that many firms in the Hamburg area have the potential to build important components. It can therefore be expected that the building of HERA will have a significant economical effect on parts of the Hamburg industry.

DESY ist jointly supported by the Federal Republic of Germany and the State of Hamburg. Building of HERA therefore requires an approval by both partners.

The Bundestag and the Senate of the City of Hamburg approved first funds for the HERA construction in the 1984 DESY-budget which will be available from the date of final approval. A law controlling the use of the land in Hamburg-Bahrenfeld, the area where DESY is located, in which the HERA construction is foreseen, was voted by the Hamburg State Parliament, the Bürgerschaft, in spring 1982. This provides the legal basis for the construction of the tunnel and the experimental halls.

Final approval of the project is expected in spring 1984. The construction work is planned to start by end of May 1984 and should be finished by end of 1987. From middle 1986 onwards the storage ring components will be installed; installation should be completed by end of 1989. The research at HERA is then expected to begin in 1990.



Deutsches Elektronen-Synchrotron DESY
Notkestraße 85
D-2000 Hamburg 52
Phone: 49-40-8 99 80, Telex: 215 124

March 1984

The HERA storage ring in Hamburg-Bahrenfeld

Due to the fast printing some misprints escaped our attention for which we ask the excuse of the reader. Please correct the following:

page 4, paragraph 1, line 7: microcosmic - para. 3, l. 3: micro-scope - para. 6, l. 9: substructures

p. 6, para. 2, l. 3: as a bright - l. 4: observe

p. 10, picture top: Ducts for housing - caption: measures 5 metres

p. 12, para. 4, l. 7: Collisions - l. 11: ultra-high - para. 9, l. 1: electron-positron

p. 15, para. 4, l. 9: correction

p. 16, para. 5, l. 2: example of an - l. 3: students in teaching - l. 5: provide for the

p. 18, para. 1, l. 4: study by DESY - para. 4, l. 3: precedent - para. 5, l. 4: boost in their - l. 12: economic - para. 8, l. 2: The civil engineering work

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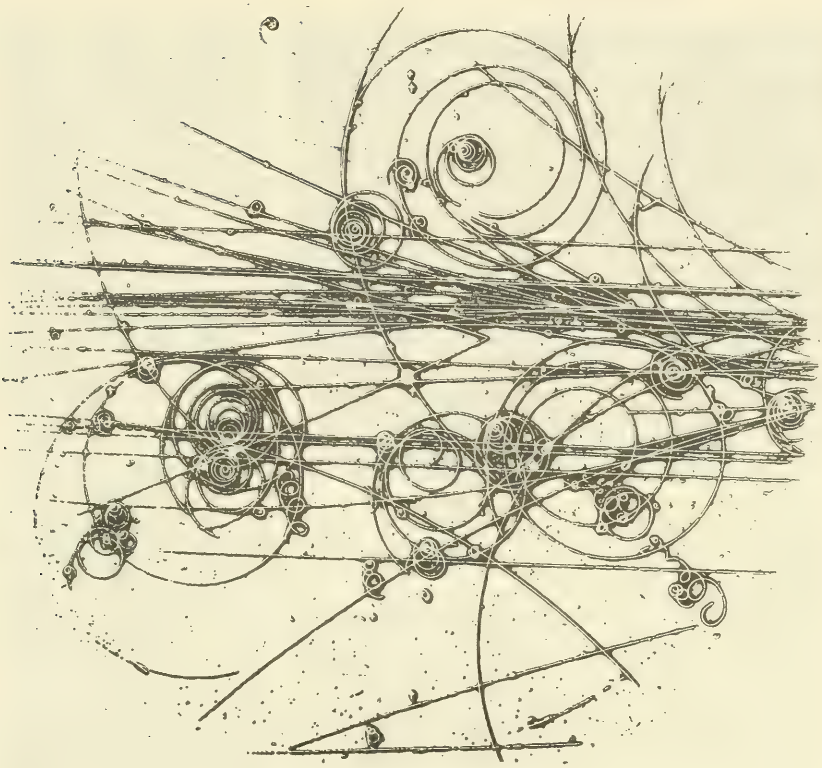
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH



CERN in brief

CONTENTS

Publications Group
Document No. CERN/PU-ED 81-8
European Organization for Nuclear Research
1211 Geneva 23 Switzerland September 1981

The European Organization for Nuclear Research, more commonly known as CERN (from the French title of the original body, 'Conseil européen pour la recherche nucléaire') is established at Geneva in Switzerland. Its laboratory extends across the Franco-Swiss frontier to the north-west of the city of Geneva.

CERN is a European organization with twelve Member States all of whom participate in a collaborative programme of physics research within a framework defined by a special Convention.

The work of the Organization is financed entirely through contributions from the governments of the Member States:

Austria
Belgium
Denmark
Federal Republic of Germany
France
Greece
Italy
Netherlands
Norway
Sweden
Switzerland
United Kingdom

Three other countries, Poland, Turkey and Yugoslavia, have the status of observer.

The prime function of CERN is to provide the physicists of Europe with particle physics research facilities of world class which could not be obtained within the resources of individual countries. This makes CERN the principal European centre for fundamental research into the structure of matter.

The research at the CERN Laboratory is largely undertaken by teams of visiting scientists who remain based at their parent university or research centre in Europe. Over 1500 physicists depend upon CERN for all or part of their research material. Visitors from over 600 different universities and institutes in Member States and elsewhere have participated in the CERN experimental programme.

In general the CERN staff is drawn from the Member States but scientists of any country may be invited to spend a limited period at CERN. Many scientists from the USA work at the Laboratory and there is a formal agreement for collaboration with Laboratories in the USSR.

The field of research is variously known as 'particle physics' (since it is the study of the behaviour of the smallest particles of matter), 'subnuclear physics' (since the particles involved are on a smaller scale than the atomic nucleus) or 'high energy physics' (since high energies are needed to perform the research). It is 'pure research' and is not concerned with the development of nuclear power or weapons.

Research is carried out with the aid of four large machines. Three of these are particle accelerators: a synchrocyclotron of 600 MeV* (the SC), a proton synchrotron of 28 GeV* (the PS) and a proton synchrotron of 400 GeV* (the SPS). The fourth, the Intersecting Storage Rings (ISR), is a system for producing collisions between two stored beams of high energy protons from the PS. Experiments are set up around the collision regions in the ISR and in experimental halls which receive high energy beams from the accelerators.

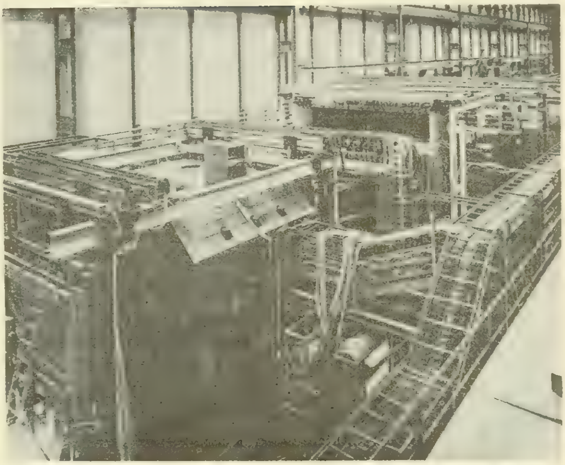
The development at CERN of new techniques for controlling particle beams has opened up new possibilities. This is exploited in the antiproton scheme in which intense beams of antiprotons are built up, fed into the ISR and the SPS and made to collide with protons.

In parallel with the physics research, development work goes on continuously to improve the accelerators, detection systems, computing facilities and other auxiliary installations and the range of equipment available at CERN is among the finest assembled for physics research at any site in the world.

*) Particle energy expressed in MeV (million electronvolts) and GeV (thousand million electronvolts)

The Research

Experiments at CERN are frequently carried out by collaborations of scientists from different institutions and from different countries. Seen here is the apparatus constructed in the North Area of the 400 GeV Super Proton Synchrotron (SPS) by the European Muon Collaboration. This is a team of more than 120 physicists from over a dozen institutions in seven countries—a truly international organization in itself. This large detecting system monitors what happens when high energy muons strike a target. (Photo CERN 164 4 78)



The research carried out at CERN is known as 'particle physics' because it studies the properties of the basic particles of which all matter is composed. Since these studies require the high energies available from particle accelerators, the research is also known as 'high energy physics'.

It is the third stage in the investigation of the nature of matter which has taken place in the course of this century. In the first stage, 'atomic physics', the characteristics of the electron cloud which surrounds the nucleus of the atom were studied. The understanding which this brought explains almost all of the features of matter as they are encountered in our daily life. The second stage, 'nuclear physics', went deeper into matter and studied the characteristics of the atomic nucleus. The gross features of these composite nuclei are now understood and the investigation has moved to a third stage, 'particle physics', which studies the behaviour of the constituent particles of matter.

In the course of this research, it has been found that several hundred different particles exist, in addition to the more familiar particles which make up the atom. Most of the newly discovered particles live only a short time after they have been created by the accelerators, and break up into other particles. By studying them, scientists can find out about the microscopic properties of all matter and about the basic laws of the three forces which govern this small-scale behaviour.

Particle physics has led to great advances in our understanding of the three basic forces—the 'electromagnetic force', which controls all electric and magnetic phenomena, the 'strong force', which acts between the particles inside the nucleus, and the 'weak force' of radioactive decay, much less powerful than the electromagnetic force, but which appears to be related to it in a profound way. (A fourth force in Nature, the 'gravitational force' is relatively insignificant on the scale of individual particles.)

The particles can be classified according to their susceptibility to the forces. Those which feel the strong force are called hadrons; those which do not feel the strong force are called leptons. Both hadrons and leptons can have electromagnetic properties.

Research in recent years has revealed that the large numbers of hadrons contain smaller objects called 'quarks'. Although no quark has been detected in isolation outside a hadron, there are strong indications that hadrons are built from quarks—of which it seems that at least five types exist. The different possible combinations of these quarks produce the multiplicity of hadrons.

CERN makes available to the physicists of Europe a range of large accelerators and detection systems for particle physics research. The experiments using this equipment, and the accompanying developments in theoretical understanding have made major contributions to this important field of basic science.

To select a few examples: a series of experiments studying the particle known as the muon, together with some refined theoretical calculations, have confirmed the validity of the theory of electromagnetism with very great accuracy.

In the study of the strong interaction, experiments at CERN have contributed a vast amount of detailed information on the behaviour of hadrons. Many new particles have been identified and their properties measured. Investigations in the energy range covered uniquely at the Intersecting Storage Rings have revealed new aspects of the structure of the proton.

Experiments with beams of the type of lepton called the neutrino have been a very fruitful source of information on the weak force. A new way in which the force can operate (the neutral current interaction) was discovered at CERN. It has many implications ranging from atomic physics to the theory of stellar evolution. It gives strong support to the theoretical attempts to find a unified picture of the electromagnetic and of the weak force.

Research at lower energies, particularly at the CERN synchro-cyclotron, is concerned mainly with investigations in nuclear physics. An on-line isotope separator at the SC has provided a wealth of knowledge on the properties of highly unstable nuclei.

History of the Organization

December 1951
UNESCO called together an intergovernmental conference of European states to consider the creation of an international research institution equipped on a scale beyond the individual means of the potential member nations.

February 1952
A second similar meeting held in Geneva ended with the signing of a Convention establishing a provisional organization, finally called the Conseil européen pour la recherche nucléaire (CERN).
Eleven governments signed the Convention: Belgium, Denmark, Federal Republic of Germany, France, Greece, Italy, Netherlands, Norway, Sweden, Switzerland, Yugoslavia. The United Kingdom held the status of observer.

May 1952
The first session of the Council was held in Paris. The statutes of the provisional organization were adopted and Professor Amaldi was appointed Secretary-General.

October 1952
At the 3rd Council meeting the decision was taken to establish the proposed laboratory of the organization at Geneva.

July 1953
The Convention establishing the European Organization for Nuclear Research was signed at the 6th meeting of the Council.

September 1954
The 'provisional' CERN was dissolved with the ratification of the Convention by a sufficient number of States to ensure 75% of the necessary financial commitment.

February 1955
The 12th European state ratified the Convention. The founder Member States were: Belgium, Denmark, Federal Republic of Germany, France, Greece, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom, Yugoslavia.

June 1955
An agreement was signed by the Swiss Government and CERN covering the legal status of CERN in Switzerland.

July 1959
Austria joined.

January 1961
Spain joined.

June 1961
Turkey was granted observer status.

December 1961
Yugoslavia ceased to be a member but retained the status of observer.

June 1963
Poland was granted observer status.

September 1965
An agreement was signed leasing to CERN an area of land on neighbouring territory in France. The extended site straddles the Franco-Swiss frontier.

December 1965
Council approved the programme for the construction of the Intersecting Storage Rings (ISR) on the new part of the site.

July 1967
An agreement was signed with the USSR State Committee for the Utilization of Atomic Energy concerning a common programme of scientific and technical research on the 76 GeV accelerator at Serpukhov.

December 1967
Council approved a series of amendments to the Convention to permit the establishment of a second laboratory with a larger accelerator.

December 1968
Spain withdrew from the Organization for financial reasons.

January 1971
All 12 Member States having ratified the amendments to the Convention agreed in December 1967, the revised Convention came into force.

February 1971
Ten Member States agreed to establish a second laboratory (Laboratory II) adjoining the extended original site (Laboratory I) in France and Switzerland for the construction of a new super proton synchrotron (the 400 GeV SPS), and voted the first budget of the 8-year programme. The States were Austria, Belgium, France, Germany, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom.

June 1972
Signature of the agreement between France and CERN revising the 1965 agreement concerning the legal status of the Organization in France.

December 1972
The lease agreement for the new land in France was signed and the 1965 lease agreement amended.

December 1974
The 'contrat de superficie' with the Swiss authorities was signed.

July 1975
A protocol was signed extending the 1967 agreement for collaboration between CERN and the high energy physics centres in the USSR, so that Soviet teams can participate in experiments at CERN.

January 1976
The two CERN laboratories were united. Management of the unified laboratory was entrusted to an Executive Director-General and a Research Director-General appointed by Council.

1979
Official Celebrations of 25th Anniversary of CERN.

The Convention

The original Convention establishing CERN entered into force on 29 September 1954. Twelve European States ratified the Convention between 30 December 1953 and 24 February 1955.

Council agreed amendments to this Convention in December 1967 to permit the establishment of a second laboratory. The amended Convention came into force on 17 January 1971, thirty days after the 12th Member State had informed the Organization that ratification had been completed. The Convention sets out the aims of the Organization and defines the programmes of activities:

(a) operation of the 28 GeV proton synchrotron (PS) and the 600 MeV synchro-cyclotron (SC);
(b) the construction and operation of the Intersecting Storage Rings (ISR) coupled to the PS;
(c) the construction and operation of a proton synchrotron for energies of about 300 GeV (now the 400 GeV SPS).

The Convention (Article II) describes the aims of CERN as follows: The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.

Member States have equal voting rights and, in general terms, decisions are taken by simple majority. Two thirds majorities are, however, required for certain matters, for example: the annual budgets, the appointment of the Directors-General, collaboration agreements with other organizations and the establishment of the scale of financial contributions. This last would largely be formal, as it is based on the net national revenues of Member States, were it not that Council may make special concessions to individual Members. If the long term commitments of a State are also involved, such as the financial ceiling of a given programme, there must be no dissenting participant. Where the long-term relationship with the Organization is in question this can only take place if no Member State votes to the contrary.

The Convention is essentially a liberal document designed to encourage collaboration on a wide basis and to give flexibility in the organization of the research so that it can meet the evolving challenge of the subject. As CERN has developed, so the collaboration between the Laboratory and the research centres and Universities inside Europe has been strengthened. At the same time the collaboration with laboratories in the same field outside Europe has increased to the point where communication is at a truly global level.

The flags of the twelve Member States and of the Canton of Geneva near the main entrance to the Laboratory.
(Photo CERN 571 5 78)

Council and its Committees

Council

The Council is the supreme body governing the affairs of CERN. It is made up of two delegates from each Member State, who may be accompanied by advisers. The Council Members and their advisers, together with the members of the Council Committees, form the links with the authorities in the Member States.

It is for the Council to agree upon the broad lines of research policy and match these with adequate resources in money and manpower. It is charged by the Convention with adopting the budget, reviewing expenditure, publishing the audited accounts of the Organization and issuing an Annual Report. The Council must also approve the Staff Rules, the Financial Rules and the Rules of the Pension Fund, which provide the main framework of administrative policy.

Heading the Council is the President who is elected along with two Vice-Presidents for one year but may serve for a maximum of three consecutive years.

The Council meets as often as is necessary but at least twice per year, in June and December. At both meetings progress reports are presented by the Director-General and at the December meeting the budget is fixed for the following year. These meetings are, in general, taken in open session but some discussions may be held in private. Council documents are prepared in English and in French with a summary in German.

The voting requirements for important decisions are laid down in the Convention. Delegates from the Member States are of equal standing and have the same rights. The relationship with the administration of the Laboratory is based on mutual trust and confidence and many delegates have been representing their country on the Council for many years. There is a long-standing tradition that difficult issues are settled by seeking a consensus of opinion which all delegates can then support.

The presidents of Council since the creation of CERN have been as follows:

At the CERN Council session in June 1981, left, Director-General Herwig Schopper with President of Council Jean Teillac. (Photo CERN 570.6.81).

1954-1957	Sir Ben Lockspeiser (UK)
1958-1960	Mr. François de Rose (F)
1961-1963	Mr. J. Willems (B)
1964-1966	Mr. J.H. Bannier (NL)
1967-1969	Dr. G. Funke (S)
1970-1971	Prof. E. Amaldi (I)
1972-1974	Prof. W. Gentner (D)
1975-1977	Mr. P. Levaux (B)
1978-	Prof. J. Teillac (F)

(In 1977, the President-elect, Prof. B. Gregory (F), died before taking office.)

Apart from the Committee of Council there are two permanent committees which give specialist advice to the Council: the Scientific Policy Committee and the Finance Committee.

Committee of Council

The Committee of Council consists of one representative per State together with the Chairmen of the Scientific Policy Committee, the Finance Committee and the European Committee for Future Accelerators.

The Committee of Council meets in private at more frequent intervals than the Council and makes the necessary preparations for the full Council meetings. It is an informal forum where Member States can present their viewpoints and delegates can freely discuss any matter.

Scientific Policy Committee

The Scientific Policy Committee (SPC) is made up of eminent scientists, chosen in their own right rather than as representatives of a specific State. Its prime activity is to provide Council with the best possible advice on scientific developments and their implications for the Organization.

Ex-officio members of the SPC are the Chairmen of the Experiments Committees and the European Committee for Future Accelerators, while the President of Council and Chairman of the Finance Committee also participate.

Finance Committee

The Finance Committee, which includes delegates from all the Member States, receives the CERN budgets and reports on them to Council, whilst at the same time it decides on the form in which CERN's accounts should be rendered. In day-to-day affairs it must be notified of any significant transfer of funds within the budgets and given prior notice of any operations which would involve overspending them.

The Finance Committee is given advance warning of CERN's requirements for important equipment or services and its approval is required for important contracts.

Experiments Committees

Three committees, chaired by scientists from outside CERN, study the proposals made by physicists in the Member States for experiments to be carried out on the CERN machines. Their recommendations are then sub-

mitted to the Research Board of CERN which is chaired by the Director-General and includes the Chairmen of the Experiments Committees, members of the Directorate and appropriate CERN Division Leaders. This Board establishes the programme of experimental particle physics research at CERN.

ECFA and ICFA

The European Committee for Future Accelerators (ECFA) was set up in January 1963, jointly by the Director-General and the Chairman of the Scientific Policy Committee following the recommendation of the Council of the previous month. ECFA is an independent body, composed of European high energy physicists, which advises the Director-General and the Scientific Policy Committee.

ECFA produced two important reports in 1963 and 1967 which were submitted to the CERN Council. They recommended the building of the ISR and a 300 GeV accelerator (now the 400 GeV SPS). In 1977 ECFA recommended the construction of a large electron-positron colliding beam machine, LEP, as the next major accelerator project for Europe.

In 1976 an Interregional Committee for Future Accelerators (ICFA) was set up by the Commission for Particles and Fields of the International Union for Pure and Applied Physics to study large-scale collaborations between the various regions of the world engaged in high energy physics research.

Location of the Laboratory

Aerial view of CERN looking over Geneva airport towards the city and Lac Léman. The underground SPS ring with associated beam lines is shown white. (Photo Swissair)

The original laboratory site at Meyrin, Switzerland, was selected in 1952. Its entrance is situated some 8 km from the centre of Geneva on the route de Meyrin which joins the N84 through Saint-Genis in France.

The site was extended in 1965 (known was Laboratory I from 1971 to 1975) and covers an area of approximately 80 ha, of which 40.5 ha are in the Swiss Canton of Geneva and 39.5 ha in the French Communes of Prévessin and Saint-Genis-Pouilly in the Department of Ain.

The adjoining land under which the 400 GeV accelerator (SPS) has been built (known as Laboratory II during the first years of the project) covers 480 ha, of which 412 ha are in France and 68 ha in Switzerland. In addition a further 572 ha (509 ha in France) are reserved for possible future developments. With the machine and most of the experimental beamlines below ground, disturbance of the surrounding environment has been minimized and the site has retained its pleasant rural appearance.

Personnel

Responsibility for the activities of the Organization is vested by Council in a Director-General. In 1971, a second Director-General was nominated to head the 300 GeV Programme (Laboratory II) in addition to the Director-General of the then existing laboratory (Laboratory I). From the merging of the Laboratories in 1976 until 1980 CERN was headed by an Executive Director-General and a Research Director-General.

From its very beginning CERN has been led by scientists:

F. Bloch (CH) 1954-55;
C.J. Bakker (NL) 1955-60;
J.B. Adams (GB) 1960-61;
V.F. Weisskopf (USA) 1961-65;
B.P. Gregory (F) 1966-70;
W.K. Jentschke (A) Lab. I 1971-75;
J.B. Adams (GB) Lab. II 1971-75 and Executive D.G. 1976-80;
L. Van Hove (B) Research D.G. 1976-80;
H. Schopper (D) 1981-.

The staff is almost completely composed of nationals from the Member States where all but the most junior posts are advertised through the press and by notifications to government departments and research centres. All staff is on a common grading system and each post has a grade associated with it. The grading runs from 1 to 14 and although there is no strict allocation of posts in proportion to a country's contribution, above grade 8 the distribution by country corresponds roughly to country population. The lower graded posts are recruited from the local region, the majority from the Pays de Gex in France.

The total number of people for whom the Organization was responsible in 1981 (excluding contracted labour and contractors' employees) is about 6000. About 3600 are staff members working at CERN under contract, the remainder being visitors. These include fellows and paid associates invited by CERN to spend some time with the Organization, together with a substantial number of 'unpaid associates' who remain on the payroll of another Laboratory while working at CERN.

Finances and Purchasing

On 31 December 1980, the five-year term of office of Executive Director General John Adams (left) and Research Director General Leon Van Hove (right) came to an end. They handed over to Herwig Schopper (centre).
(Photo CERN 504 12.80)

Each Member State pays a fixed contribution to the capital and operating costs of the CERN programme according to a scale established every three years on the basis of the net national income figures for the previous three years supplied by the United Nations. However, no single State can be required to pay a contribution in excess of 25% of the programme.

The relevant percentage contributions to the budget were last fixed as follows:

Austria	2 53
Belgium	4.66
Denmark	2 49
France	21.70
Germany	25.00
Greece	0.36
Italy	12 73
Netherlands	6.18
Norway	1.79
Sweden	4.30
Switzerland	4.13
U.K.	14.13

Budgets

The financial year runs from January 1 to December 31 and the budget is drawn up in Swiss Francs.

The Director-General submits to the Finance Committee the budget proposals which are then transmitted to the Council with the report of the Committee. The budget procedure is normally based upon a four-year rolling system known as the Bannier Procedure. In December of each year, the Council votes the budgets for the following year and makes firm estimates (at current prices) of the budgets for the year after; at the same time it gives a provisional estimate of the sums that can be expected in the following two years.

Some significant figures (in units of million Swiss Francs):

1981 Budget	610
Cost of 28 GeV PS ('59 prices)	120
Cost of ISR ('65 prices)	326
SPS programme ('70 prices)	1089

Contracts and Services

On average about 50% of the funds of CERN are spent on salaries. The remainder is spent on the purchase of equipment and the payment for supplies and services.

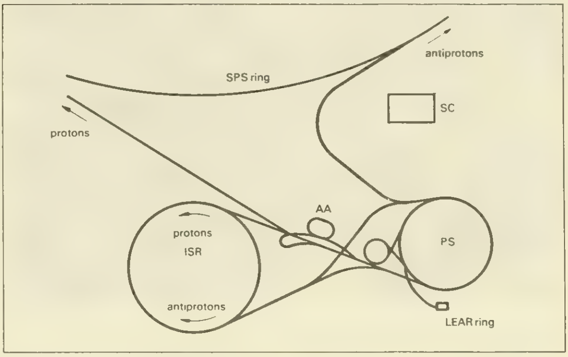
The acquisition of important items of equipment and the provision of major services is normally the result of competitive tendering. Whenever possible, invitations to bid are addressed only to companies established in the Member States. The contract is normally awarded to the lowest bidder who can fulfil the necessary technical requirements and delivery time. It is the responsibility of the Finance Committee to see that these conditions are met in placing the contract.

Prior agreement is needed from the Finance Committee for all contracts with a value of more than 750 000 Swiss Francs and for any contract in excess of 200 000 Swiss Francs where it is proposed to go direct to a supplier without calling for bids.

CERN is not required to pay customs duty on the equipment and material it buys and local taxes which have been added are reimbursed by the host countries.

High Energy Machines

Schematic diagram showing the location of the high energy machines on the CERN site and the beam lines that link them.



At CERN, a complex of particle accelerators provides the high energy particles for research.

The principal parameter of an accelerator is the maximum energy to which it can accelerate the particle beams. This energy is expressed in units of electronvolts, eV (the energy given to a particle carrying unit charge when it crosses a potential difference of one volt). The CERN machines include a synchro-cyclotron (SC) of energy 600 MeV (million electronvolts) and a proton synchrotron (PS) of energy 28 GeV (thousand million electronvolts). A super proton synchrotron (SPS) of 400 GeV was commissioned in 1976.

Other parameters of significance are the intensity of the pulses of protons produced and the rate at which the machine can be pulsed. For the experimenter, the energy spread of the beam, the ejection efficiency and the length of time the beam can be held in the machine whilst a fraction is continuously extracted are also important factors.

The PS feeds Intersecting Storage Rings (ISR) which are not primarily accelerators but a pair of interlaced annular chambers in which particles, previously accelerated in the PS, are stored, circulating continuously round the rings in opposite directions. The two beam currents collide almost head-on at eight intersection points distributed symmetrically round the circumference.

In the antiproton scheme, antiprotons are stored in the Antiproton Accumulator (AA), and fed to the PS for initial acceleration before being passed to the SPS for final acceleration to 270 GeV. In the SPS, proton and antiproton beams are accelerated in opposite directions and made to collide together at two points in the ring. Protons and antiprotons also collide in the ISR.

For the future, construction is envisaged of a large (27 km circumference) electron-positron colliding beam machine, LEP.

Synchro-Cyclotron (SC)

The 600 MeV synchro-cyclotron, the SC, was first commissioned in August 1957. It provided accelerated protons for a full programme of nuclear physics experiments from then until June 1973 when it was shut down for a series of major modifications aimed at increasing its output by an order of magnitude.

When the SC restarted in January 1975 little remained of the old machine except for the main magnet (and the building).

Further modifications have enabled the machine to accelerate heavier ions such as helium-3 and carbon-12 to energies of 910 and 1030 MeV respectively.

In the SC, particles are injected into the middle of a vacuum chamber set between the 5-m poles of a 2500 ton, fixed field electromagnet. Grouped into bunches, the particles travel in a circular path crossing and recrossing, on every turn, the gap formed between two electrodes in which an oscillating electric field is established. The frequency of this field is synchronized to the orbiting frequency, so that the particles receive an increase in energy of about 20 keV per turn. As they gain energy, the radius of the orbit increases and the particles spiral out to the periphery where they can be extracted as a bunch, pulled out progressively over many revolutions or made to strike an internal target.

The electric field is created between an earthed strip and a hollow Dee which forms part of a radio-frequency (r.f.) resonant line. For protons the accelerating frequency must be capable of changing in each cycle from 30 MHz to 16.6 MHz as the effective mass of the protons increases with increasing energy. In the modified SC this frequency change is produced by a tuning capacitor, a 3-bank, 16-tooth rotary condenser capable of running at up to 450 Hz, determining the repetition rate of the acceleration cycle.

Modifications have included a completely new ion source and power supply, as well as new radiation cooled targets and a system of ejection which gives a duty cycle far superior to what has been possible before. The machine can now accelerate a maximum internal proton current of about 7 μA mean intensity and the extraction efficiency is about 70%. To handle heavier ions, the accelerating frequency must be lowered. This is done by fitting an extension line between the Dee and the rotary condenser.

The SC has three experimental areas—one room fed with pion or muon beams derived from internal targets; a second room, on the other side of the accelerator which receives beams of either pions and muons from an external target or the extracted beam of accelerated ions, and an un-

The new control room at the PS 28 GeV proton synchrotron.
(Photo CERN 225.11 80)

derground area served by the extracted beam, where a special short-lived isotope production and analysis unit named ISOLDE is installed.

Proton Synchrotron (PS)

The 28 GeV proton synchrotron was commissioned in 1959 when it became the first machine in the world to accelerate intense proton beams to energies in this range. It was also the first proton machine to be completed using the 'alternating-gradient' or 'strong focusing' principle. It is, and will remain for many years, the main source of accelerated protons for particle physics research in West Europe. For protons, the present main tasks of the PS are to supply accelerated particles to the 400 GeV SPS, to the ISR colliding beam machine, to provide particle beams for experiments in the 20 GeV range, and to supply a proton beam to produce the antiprotons used in the Antiproton Accumulator (AA). This requires a wide variety of proton beams. In addition, the PS also accelerates antiprotons for the SPS and the ISR (see page 10).

More than 10^{13} protons in 20 bunches are accelerated around a circular path 200 metres in diameter once every few seconds, the intensity and cycle time depending on the use to which the machine is being put. The protons are obtained from hydrogen gas, taken to 750 keV by an electrostatic generator and then fed into a linear accelerator (Linac) which takes them to 50 MeV. At this energy the proton beam enters the Booster, a synchrotron comprising four 50 m diameter superposed rings, which accelerates the protons to 800 MeV before injection into the main ring of the PS. The four Booster rings are filled in turn from the linac (the variation of intensity is obtained by varying the number of turns injected); then the beam energy is raised by radio-frequency (r.f.) cavities of very compact design, with guidance and focusing around the machine being assured by 32 four-channel bending and 48 four-channel quadrupole magnets. The four rings are then emptied in turn into the PS.

In the main ring of the PS the protons are accelerated by 11 r.f. cavities with a frequency range of about 3 to 10 MHz, and they travel in an annular vacuum vessel of elliptical cross-section (14.5 × 7 cm) held at a pressure of about 2×10^{-8} torr. The protons are maintained in orbit in the ring by a magnetic field rising to 1.4 T and produced by 100 magnets, each 30 tons in weight. The proton velocity reaches about 99.94% of the speed of light in about half a million orbits, and at maximum energy the proton mass becomes about 30 times greater than its rest mass.

The PS works a flexible schedule, often operating continuously for 32 days followed by 3 days for maintenance and modifications. During one supercycle of about 10 seconds, the required types of particle beam can be supplied, each at the required level of intensity and with the proper beam characteristics. The main task of the PS is to act as the injector for the SPS, which has 11 times the circumference of the PS, providing protons at an energy of 10 GeV. For this purpose the beam is bunched at 200 MHz (the r.f. frequency of the SPS), then a method of continuous transfer is used in which protons are peeled off from the beam circulating in the PS during 10, 5 or 3 turns depending whether the process is repeated once or more times during a supercycle (multibatch filling). The PS also has to fill the two rings of the ISR with protons of the required energy and supply protons for antiproton production. There is also a programme of physics research directly with PS protons.

For this latter purpose the protons can either be ejected from the ring, using one of the two available ejection systems, or directed to a target mounted inside the vacuum chamber itself. The ejected proton and secondary particle beams (beams of different types of particle produced in the high energy collisions which take place in targets) are sorted and guided by electrostatic and magnetic fields as they are directed towards detection equipment in the experimental areas. It is, for instance, possible to have a number of bunches extracted rapidly and a certain fraction of the beam at in-

termediate energies led to an internal target during the acceleration phase. Once top energy has been attained, beam is debunched before slow extraction.

Intersecting Storage Rings (ISR)

The ISR consist of two interlaced rings of magnets (similar to those in the PS), 300 metres in diameter. These magnets guide and focus the protons through vacuum tubes which intersect at eight positions round the circumference. Proton beams, accelerated in the synchrotron to energies up to 26 GeV, are injected into the two rings in such a way that they travel in opposite directions relative to each other. The beams can be further accelerated up to 31.4 GeV and brought into almost head-on collision in the intersecting regions. Big experimental halls have been constructed over two of these regions and five others are also available for experiments.

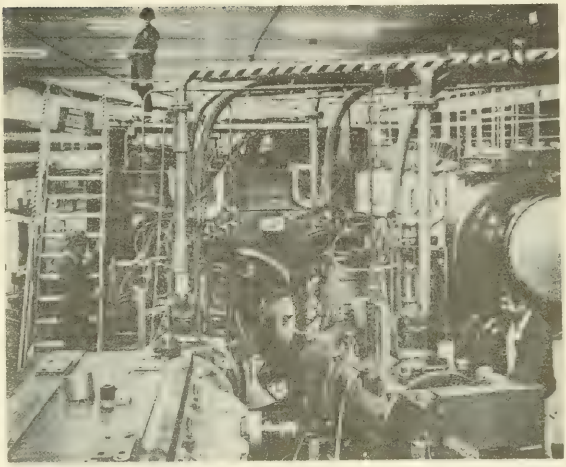
With colliding beams, almost the whole of the kinetic energy given to the protons can go into the creation of new particles or the transformation of the protons, whereas when bombarding stationary targets, most of the energy goes into the recoil of the particles. From this point of view, the ISR are equivalent to a conventional accelerator of almost 2000 GeV. In addition to protons, the rings can hold other particles provided by the Linac-PS complex. So far proton, antiproton (see page 10), deuteron and alpha particle interactions have been observed.

The rate of interaction is proportional to the product of the two beam intensities and if this is to be of an acceptable value, many pulses from the PS must be stacked together.

In building the ISR, extremely high precision has been required in all the main components. The magnet guidance and focusing system must be of exceptional stability and precision.

The radio-frequency (r.f.) system has to produce very stable accelerating voltages and be immune from beam loading problems. To achieve maximum beam stability, it must at the same time offer very low impedance to the circulating beams.

Intersection 8 of the Intersecting Storage Rings, with the superconducting magnets of the low-beta insertion which increases the available luminosity. (Photo CERN 397.10 80).



Crucial to the ultimate performance attainable is the quality of the vacuum. In the two kilometres of vacuum tube in which there are some 10000 demountable joints, the mean pressure is about 3×10^{-12} torr.

The commissioning of the machine was several months ahead of schedule and on 27 January 1971 two beams were made to collide for the first time.

Since that time performance has been steadily improved and currents of over 50 A have been successfully stacked. Luminosities now achieved (over 3×10^{31} cm^{-2} s^{-1}, and over 10^{32} using a superconducting low-beta insertion at intersection region I8) are many times the design figure and once filled, the rings can run continuously for over 70 hours without excessive deterioration of the beam quality. Operation is now mostly at 31 GeV.

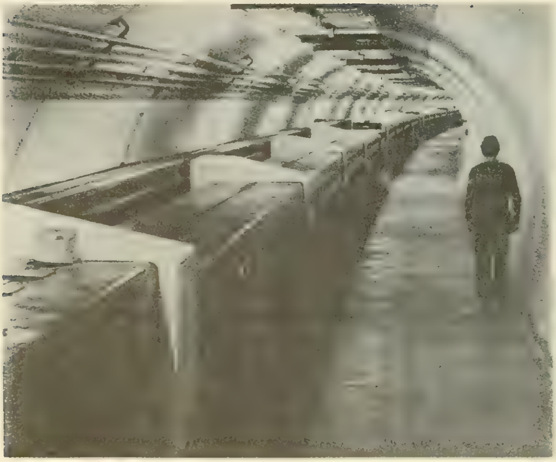
Experiments are clustered around six of the intersection regions. The two most massive installations are in intersections I4 and I8. In the former a 1000 ton split field magnet has been installed which creates a field of opposite sign on the two sides of the intersection point. The magnet aperture is filled with particle detectors called multiwire proportional chambers and the magnet can be surrounded by a large number of scintillation counters for simultaneous use by several experimental groups. The Axial Field Spectrometer at intersection I8 uses a specially-constructed 300 ton magnet and detecting apparatus including a 200 ton uranium calorimeter.

400 GeV Super Proton Synchrotron (SPS)

The 400 GeV proton synchrotron was commissioned in 1976 and then became the world's largest accelerator. Protons are injected at 10 GeV from CERN's original 28 GeV proton synchrotron (PS) and are accelerated to 400 GeV in the SPS before being extracted for use in physics experiments in the West and North experimental areas.

The SPS is capable of operating at 450 GeV when required and a record

An arc of the SPS ring showing bending and focusing magnets in place.
(Photo CERN 210.11.76)



500 GeV was attained in December 1978. The beam intensity in each 12-second pulse rose past the design figure of 10^{13} protons before the end of 1976, and reached a record of 2.7 × 10^{13} in 1980 at the end of the first four years of operation.

In 1980-81 the SPS stopped operation during 10 months for conversion into a proton-antiproton collider (see page 10). This involved major civil engineering changes to provide two large collision regions for experiments, and to allow for the injection and acceleration of antiprotons. The counter-rotating bunches of protons and antiprotons are injected at 26 GeV and subsequently accelerated to 270 GeV where they are held on collision orbits for 24 hours whilst the experiments in the two collision areas take data. First proton-antiproton collisions were seen in July 1981. The operation of the SPS is divided between this collider mode (about 30% of the time) and fixed target physics in the West and North Areas (about 70% of the time).

The SPS is built underground in an annular tunnel of 2.2 km diameter and 4 m internal diameter. This tunnel is at a depth varying from 23 m to 65 m depending on the ground surface profile. The surface area covers 480 ha, of which approximately 1/7 is in Switzerland and the rest, including the main laboratory buildings, assembly hall, and experimental areas, are in France. Only about 100 ha are enclosed, the remainer of the area continuing as farmland and woods as before.

Although nearly circular, the ring contains six long straight sections each with an access pit and associated surface buildings for auxiliary equipment. Four of these pits are in France and two in Switzerland. Two of the long straight sections are used as proton-antiproton collision points, in underground halls, which house the experimental equipment. One straight section is used to house the 200 MHz r.f. cavities for accelerating the particles, one for proton injection and beam dumping, one is used for extraction to the North experimental area, and one for extraction to the West experimental area. The latter is also used for injection of the antiprotons in the same channel but in the opposite direction.

The particles are guided round the ring by 744 bending magnets each 6 m long and are focused by 216 quadrupoles distributed regularly round the ring. The positioning of these magnets is very important and required precise surveying. They are in fact positioned to within about 0.1 mm. The tunnel was dug by a full-face boring machine which completed its 7 km-long circumference within centimetres of the planned path.

The power for the magnets is provided by solid-state rectifiers fed from a special 380 kV power line which connects the SPS complex to the EDF generating station at Génissiat. The average power consumption of the magnet is about 35 MW with a peak instantaneous load of 160 MW. Cooling is through a closed circuit water system which is, in turn, cooled by a special supply from Lac Léman. After refrigeration in cooling towers this water passes into a local stream and subsequently into the Rhône.

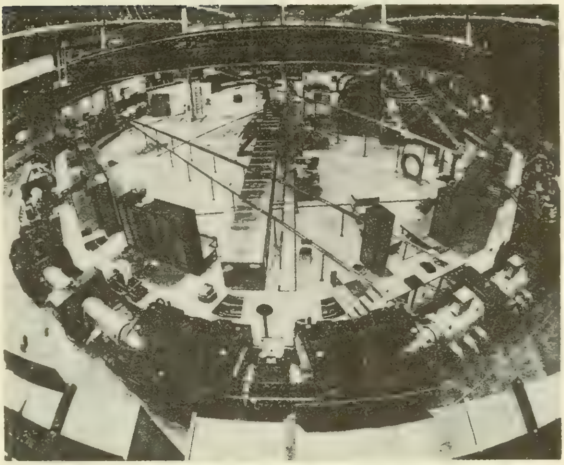
The purpose of the magnets is to bend and focus the particles into a beam a few centimetres across, and to keep it well within the walls of the 7 km-long vacuum chamber which goes through the middle of all the magnets and varies in cross-section from a 9 cm diameter cylinder to a 16 by 5 cm ellipse. To keep the beam within this chamber requires close tolerances on the magnet fields, plus a measurement and correction system based on 216 pick-up electrodes and low field correction magnets.

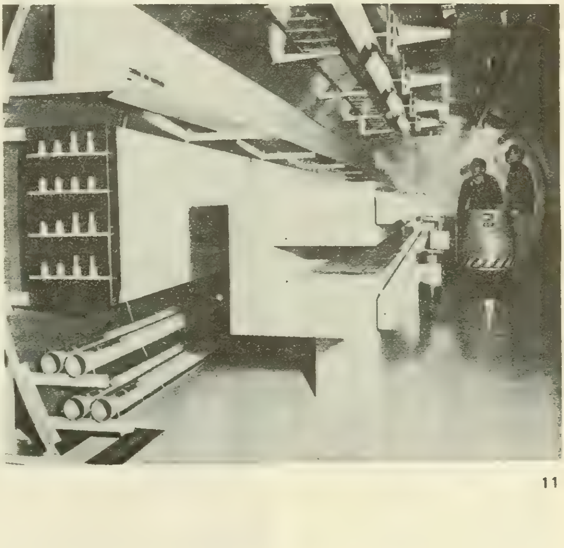
Antiproton Scheme

In 1978, experiments at CERN showed how beams could be tightly controlled using new 'cooling' techniques, thus enabling new types of particle beams, such as antiprotons, to be accelerated and stored. This opened the door to an ambitious enlargement of CERN's research facilities. In this new scheme, antiprotons are brought into head-on collision with high energy protons. This provides very high collision energies and probes new areas of physics.

Above, the magnet ring of the Antiproton Accumulator, heart of the CERN antiproton project. (Photo 582.10.80).

Below, a mock-up of the LEP tunnel. (Photo CERN 423.5.81).





Antiprotons are produced by bombarding a target with protons from the PS. The low energy antiparticles are fed into a specially-built accumulator ring (AA) where cooling is applied to produce a well-defined beam. Once a sufficient level of antiprotons has been built up in the accumulator, they are fed back to the PS for acceleration ready for injection into the SPS or the ISR. The PS also supplies the necessary protons to the SPS and the ISR. Protons and antiprotons are injected into the SPS at 26 GeV instead of the 10 GeV used for producing protons for fixed target experiments.

Once in the SPS, the proton and antiproton beams circulate in opposite directions and are accelerated to 270 GeV, finally being brought into head-on collision. Special detecting equipment set up at two places in the ring monitors the results of these interactions. The collision energy is far in excess of anything attainable with other existing machines, being equivalent to that produced by a fixed target accelerator producing 150,000 GeV protons.

Antiprotons can also be decelerated in the PS to feed a Low Energy Antiproton Ring (LEAR), catering for a range of new low energy experiments.

LEP

For several decades proton machines have been the sources of the highest energy phenomena. It is easier to accelerate protons than electrons because electrons give off energy (known as synchrotron radiation) as they orbit a ring and the acceleration system has then to replace this energy, as well as providing for further acceleration, in order to increase the energy of electrons.

However the realization that the proton itself has a structure also implies that collisions between protons are collisions between composite systems and their effects can therefore be complicated to analyse. Collisions between electrons are, to the best of our present knowledge, collisions between 'point-like' objects with no structure and are less complicated to analyse. Moreover, since beams of positrons (the antimatter equivalent of

Detectors

the electrons), are readily available, electrons and positrons can be accelerated and stored in the same ring and can annihilate into pure energy when they collide, which also simplifies the analysis of what is happening.

Up to now, the highest energy which has been reached in electron-positron storage rings is around 20 GeV per beam. The LEP project aims to take this to 50 GeV in a first phase with the potential to raise this above 100 GeV later. This new high energy range is required in order to test definite theoretical predictions emerging from our present understanding of matter. Also in the new energy range, phenomena traditionally associated with the effects of the weak force should have grown to be equally as powerful as those traditionally associated with the electromagnetic force. What happens when this occurs has never been investigated before.

As proposed, the LEP project would consist of a single ring with a continuous vacuum tube, a few centimetres in diameter and about 27 kilometres in circumference, in which electrons and positrons would circulate in opposite directions. The tube would be surrounded by magnets to direct the particles around the ring and to keep the electrons and positrons focused in narrow beams. Radio-frequency accelerating cavities would accelerate the particles and replace energy lost by synchrotron radiation.

The ring would be housed in a tunnel of 4 metres diameter excavated deep underground adjacent to the present CERN site. Electrons and positrons would be injected into LEP after preliminary acceleration in the existing synchrotrons. Thus the existing machines and LEP would be linked which is one of the reasons in favour of building LEP at CERN. Initially enough equipment would be installed to accelerate the particles to 50 GeV.

LEP would be built in such a way that its peak energy could be taken as high as 130 GeV if appropriate superconducting acceleration systems become available. Also the link with the existing proton synchrotrons opens up the possibility later of electron-proton collisions or of the acceleration of protons in the LEP tunnel.

In its bare essentials every experiment comprises an incident beam of particles, a target (which can be another beam) and a series of detectors for determining the electric charge, mass, energy and angular distribution of incident and emergent particles. Magnetic fields curve the trajectories of charged particles according to their charge, mass and speed, and the angular distribution is given by the coordinates of their tracks. From these data, the behaviour of the particles during the process can be inferred.

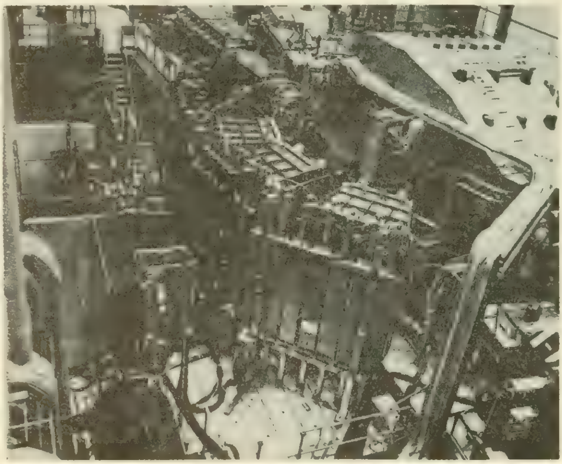
The particles are very small (of the order of 10^{-13} cm) and their lifetimes can be very short (as low as 10^{-24} s). It is therefore not the particles themselves that are observed but the effects they produce. The majority of these depend upon the ionization that is caused by a charged particle traversing a medium, be this solid, liquid or gas. Two main types may be identified—electronic detectors and bubble chambers. In neither will a neutral particle produce a direct effect.

Electronic detectors and bubble chambers are increasingly being used together in 'hybrid' detecting systems. At CERN, the large BEBC bubble chamber has been equipped with auxiliary electronic counters to provide additional information. A major new project—the European Hybrid Spectrometer—incorporates both bubble chamber and electronic detection equipment. This incorporates a specially-built rapid cycling bubble chamber, capable of taking photographs at a rate of up to 25 exposures per second.

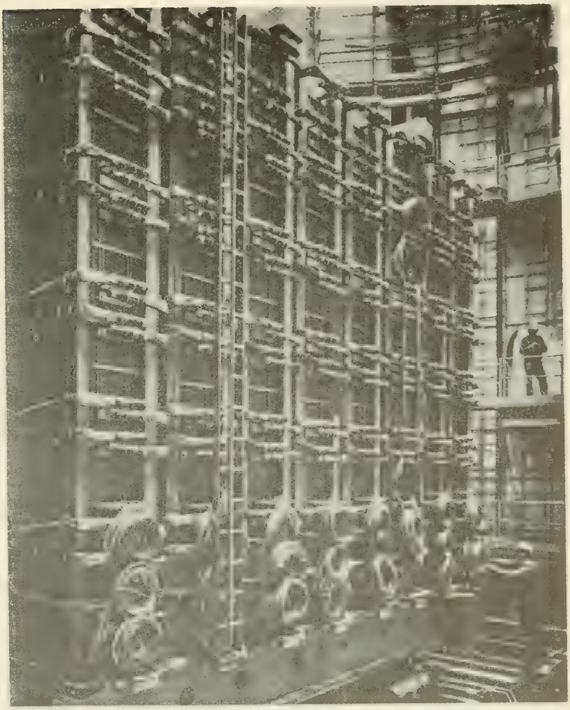
Electronic Detectors

The majority of experiments in the CERN experimental programme use electronic detectors in which arrays of counters are set up around a target onto which the beams are directed. The beams may be of protons or secondary particles produced by the interaction of the primary beam and a target further up the line.

The Split Field Magnet (SFM) at Intersection 4 of the ISR surrounded by detectors (Photo CERN 325 11 77)



Assembly of the huge detector of the UA1 experiment for the CERN antiproton project.
(Photo CERN 224.1.81).



There are several types of counter in use. The scintillation counter is constructed of a scintillating material which records the passage of a charged particle as a tiny flash of light. This is converted by a photomultiplier to an electronic signal which is amplified and passed to the data-collection system. The scintillation counter enables very precise measurements of the time of passage of a charged particle to be made and its very rapid response leads to its use in 'triggering' other slower detectors.

In the Cherenkov counter the passage of a charged particle at a velocity higher than the speed of light in the counter material emits a shock wave of light at an angle which is related to the velocity of the particle. These counters are also used in conjunction with photomultipliers and have the particular advantage that they can be arranged to pick out only particles of a certain velocity range, and thus, in conjunction with information on the particle momentum, enable the particle to be identified.

Chambers using gas discharges have been developed in a variety of forms. They record the position of a charged particle usually by detecting the electrical disturbance between parallel planes of conductors. Initially these planes were of foil and the particle location could be seen and photographed as a spark.

In modern chambers the conductors consist of fine stretched wires, the direction of which changes from plane to plane so that a coordinate system of spark location can be used with a purely electronic read-out. In variants of these, the streamer chamber, the multiwire proportional chamber, and the drift chamber, the spark is not allowed to develop fully, which decreases the time during which the chamber is insensitive to the passage of further particles. Detection systems based on these units can locate a particle track to a fraction of a millimetre and identify the time of passage to a nanosecond.

As well as being used in individual experiments, electronic detectors are also widely used in general-purpose spectrometers serving a range of different experiments.

One such spectrometer is the Omega installation in which the central electronic counters are operated in the aperture of a high field superconducting magnet. Different configurations of the detectors in the magnet are possible. The assembled data are handled directly by a computer, and events can be visually reconstructed afterwards to give help in the analysis.

Other large-scale electronic detectors include the equipment built for muon experiments in the North Area of the SPS 400 GeV proton synchrotron, the detectors in the West Area for neutrino experiments and the detection systems installed at the SPS to observe proton-antiproton collisions.

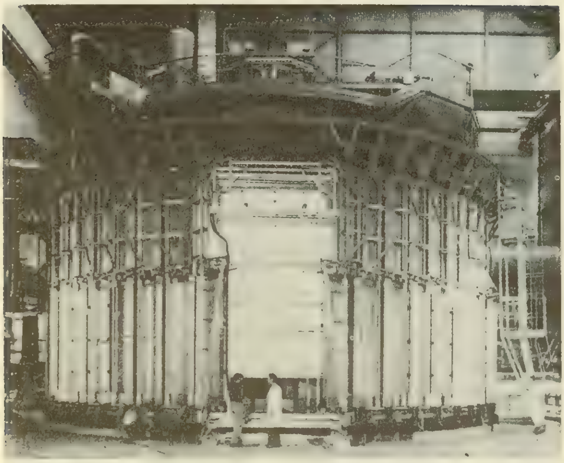
Bubble Chambers

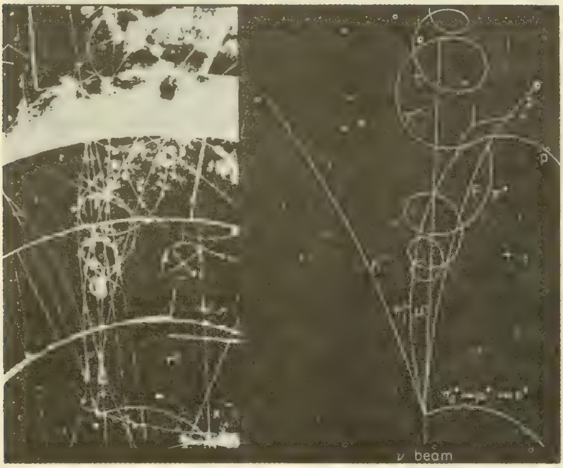
Bubble chambers have the advantage of recording all the charged products of the particle interactions (apart from the limitations imposed by the finite size of the bubble chamber).

The operating principle is to retain a

Above, the mighty 3.7 m Big European Bubble Chamber (BEBC) is now almost surrounded by a shield of additional electronic equipment to detect muons. BEBC's superconducting magnet is the largest single store of inductive energy in the world. (Photo CERN 374.1.77).

Below photograph (left) and explanation of the production and subsequent decay of a charmed baryon in a neutrino interaction in the BEBC bubble chamber.





volume of liquid at a temperature and pressure such that it is on the point of boiling. When the pressure is abruptly reduced the liquid boils preferentially along the tracks of charged particles forming lines of bubbles where ionization has taken place.

These tracks are usually photographed by several cameras (to build up a three-dimensional picture for analysis) before the volume is recompressed to prevent general boiling of the liquid. The chamber is usually located in a high magnetic field so that the trajectories of the charged particles are curved and measurements of the curvature yield information on the sign of the electric charge and on the momenta of the particles.

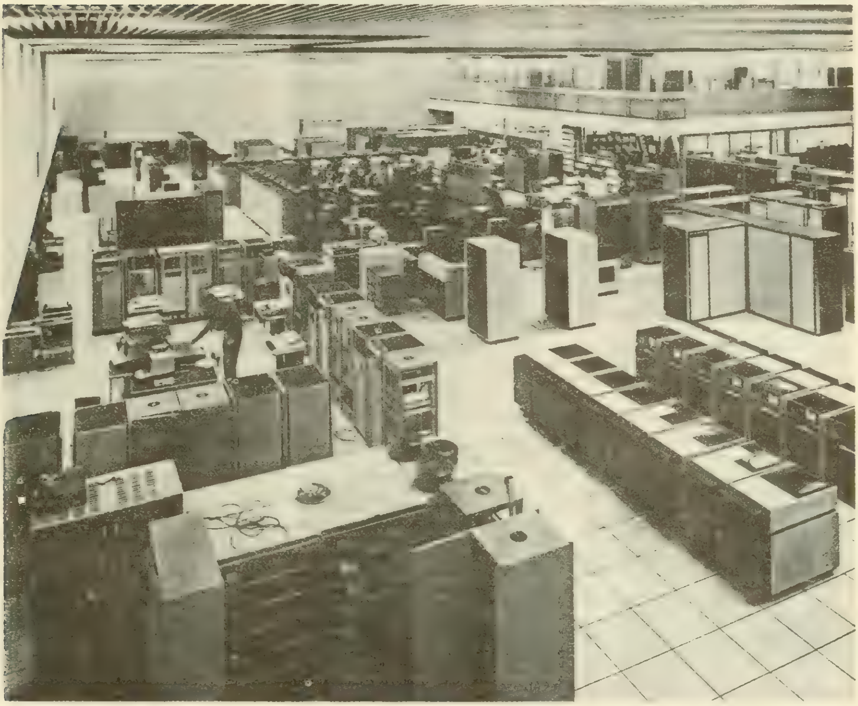
The liquid in the chamber may be hydrogen, which presents the simplest target (a proton), or deuterium (proton plus neutron) which gives the nearest approach to a free neutron target, or a heavy liquid (such as propane or freon).

The big chamber in use at CERN is a 3.7 m liquid hydrogen bubble chamber called BEBC (Big European Bubble Chamber), built under a tripartite agreement between CERN, France and Germany. The chamber body is a domed stainless steel vessel terminating in a cylinder in which a large piston operates. The inside of the chamber is covered with Scotchlite to give bright field illumination and the volume is viewed by four cameras mounted in portholes in the dome and surrounded by annular flash tubes. The chamber is surrounded by a superconducting magnet which can generate a field of up to 5 T. The chamber, which came into routine operation in 1975 for experiments on the PS, can be used with hadron and neutrino beams from the SPS. It can be supplemented with a track sensitive target, a plastic-walled tank usually filled with liquid hydrogen and immersed in a denser liquid such as a neon-hydrogen mixture to ensure more events within the chamber.

Other much smaller bubble chambers are used together with electronic detectors in specially-developed hybrid systems. In the bubble chamber field, increasing use is also being made of new techniques such as holography.

Data Handling and Computing

The main computer centre at CERN, housing a powerful array of processors. (Photo CERN 186.12.80).

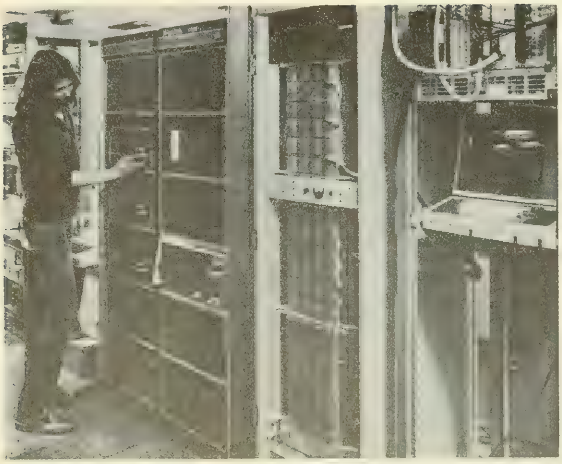


Over the past 25 years, progress in experimental high energy physics has continually made full use of the most recent developments in electronic computers and related fields. In a typical experiment, hundreds of thousands, or even millions, of particle interactions have to be sifted to obtain results of interest. If the detecting apparatus is not to become swamped, fast and powerful on-line data handling is required. Off-line, the analysis of the stored data often involves long and complex calculations. This requirement for fast on-line data handling coupled with a large off-line processing load is one of the most distinctive features of CERN's computing.

On-line data handling

There are over 250 computers installed at CERN, of which the majority are used in physics experiments for data acquisition and/or equipment monitoring and testing. Larger experiments are increasingly turning to 32-bit minicomputers, powerful enough to carry out off-line data analysis. As far as possible, equipment is now standardized, using minicomputers manufactured by Norsk Data and Digital Equipment. The standard CAMAC electronics interface is widely used, although faster systems are being developed to cater for new requirements at higher data-taking rates. Increasing use is also being made of microprocessors. Recent advances in microcircuitry have provided fast, inexpensive logic units which can be

The application of microprocessors at CERN is increasing. Seen here (right) is the 168/E which can provide a significant amount of power, on-line or off-line.
(Photo CERN 586.3.81).



used to build powerful processors for data acquisition and filtering to supplement traditional hardwired electronics.

The Computer Centre

The central computer service is based on two distinct systems, one from Control Data Corp, consisting of a CDC 7600 'front-ended' by a Cyber 170-720 and a Cyber 170-730, and the other containing IBM (or IBM compatible) equipment, including an IBM 3081 processor.

The 7600 is a large and extremely fast 60-bit word-length computer well suited for precision calculations. At CERN, it runs only batch jobs and has no peripherals other than its disks. Input and output of work and data for the 7600 are handled by the two Cyber front-end machines. For batch mode, the system is accessed through RIOS (Remote Input/Output Stations) across the site. The CDC system also supports on-line terminals. The IBM machines are accessed primarily through terminals working under a timesharing system.

Communications

In addition to a large increase in the number of computers in use at CERN, there has also been a general transition towards accessing these computers from remote terminals. Data communications thus play an increasingly important role.

The large INDEX switched private cable network allows over 600 terminals to access over 40 host computers. In addition, some external institutes are connected to INDEX through dedicated telephone lines. SUPERMUX supports up to 70 display terminals accessing the central CDC computers. The CERNET packet-switched communications network allows data to be sent between users' computers, including the central CDC and IBM machines. In this way the power and facilities of the central computers can supplement an experiment's own online computer. CERNET is also being linked to national data networks. Experiments have been carried out to investigate the feasibility of very high speed (megabit per second) data transmission between CERN and other national centres using the European Space Agency's experimental communications satellite OTS.

Other applications

Besides data handling and processing for physics experiments, there are many other uses of computers at CERN. The PS, ISR and SPS all have computer-based control systems. The SPS uses some 40 Norsk Data minicomputers distributed around the ring and its beamlines. The PS was originally controlled manually, but now uses a system of Nord-10s modelled on that developed for the SPS. The original ISR computer control system, based on a pair of Ferranti Argus 500 computers, has now been extended using Nord-10s.

An important specialized application is in the analysis of the many thousands of photographs of particle interactions from bubble chamber film. An additional computing load comes from administrative tasks at CERN, which are being handled more and more by the central computers. An IBM 4331 is used for payroll, budgeting and planning.

European Organization for Nuclear Research

Annual Report 1984

The following Report is published in accordance with the provisions of article V. 2(f) of the Convention for the establishment of a European Organization for Nuclear Research. It gives an account of CERN's activities in 1984.

Thirtieth Annual Report of the European Organization for Nuclear Research, Geneva

ISSN 0304-2901

Foreword

It has been a most gratifying year in which to conclude my mandate as President of the CERN Council because the highest accolade of the scientific community, the Nobel Prize for Physics, has been awarded to two of CERN's most distinguished staff. This was in recognition of the success of the proton-antiproton collider and of the discoveries of the W and Z particles. Through this award the work of the whole Laboratory has been honoured.

Far from resting on these laurels, the determination to ensure that CERN remains at the forefront of particle physics has been sustained throughout 1984. Many fine results came from the present experimental programme, the collider performance was significantly improved, and a start was made on its improvement programme. The construction of the large electron-positron collider (LEP), despite some problems in the first half of the year, remained on schedule, and the preparations for the four mighty LEP experimental facilities were most impressive. With these investments for the future, we have good reason to hope that CERN can retain a leading position for many years to come.

In September we celebrated the thirtieth anniversary of the creation of CERN with a ceremony which was honoured by the presence of King Juan Carlos of Spain. This was a most appropriate way to mark the welcome return of Spain to the Organization. We also had a closing ceremony for the Intersecting Storage Rings, with regrets at their premature demise to make way for LEP, but also with the knowledge that their remarkable performance has shown the way for hadron colliders.

The vitality of the CERN Laboratory stems from the abilities and the enthusiasm of its staff. It has therefore been very satisfying to see the positive evolution of the relationships between the staff, the CERN management, and the representatives of the CERN Member States during the past few years. The channels for communication and discussion are now more solidly in place and I have every hope that, with a constructive attitude on all sides, the remarkable spirit, which has always prevailed at CERN, will continue to flourish.

I have greatly enjoyed my participation in the work of this outstanding Laboratory. It has been an honour to lead the Council, and I have had the privilege and good fortune to hold this office at a time when CERN has reached new peaks of scientific and technical prowess. I am convinced that further exciting physics lies ahead in which CERN will play its full part. I rejoice also in the wonderful spirit of co-operation in which scientific resources from thirteen nations are pooled at CERN. May this continue to serve as an example of what may be achieved when nations work together, united in a common aim.

Alec Merrison

Sir Alec Merrison
President of Council

Contents

History

... The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published...

Extract from the Convention for the establishment of a European Organization for Nuclear Research. Article II — Purposes.

By the late 1940's, nuclear physicists in Europe had realized that further advances in pure research on a par with those taking place in the United States could only come through the construction of particle accelerators of a size and cost beyond the means of individual nations. Under the stimulus of a number of leading scientists, UNESCO sponsored an intergovernmental meeting in December 1951 to consider the practicability of a joint European nuclear laboratory.

At a second meeting in February 1952, 11 nations signed the Agreement which established an interim body which was to be known as the "Conseil européen pour la recherche nucléaire". So the acronym CERN came into being and has remained ever since the name by which the Organization is best known. Over the next 12 months, the structure and programme of the permanent organization was worked out, and, between July and December 1953, the Convention was signed by 12 States which established the European Organization for Nuclear Research. The founding States were Belgium, Denmark, France, Germany (Fed. Rep.), Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and Yugoslavia. With the entry into force of the Convention on 29 September 1954, the new CERN formally came into being.

Subsequently, Austria joined the Organization in July 1959 but, at the end of 1961, Yugoslavia had to withdraw for financial reasons. Turkey became an observer State in June 1961, and was joined by Yugoslavia in 1962 and one year later by Poland.

Spain entered the Organization in January 1961, but financial pressures forced her withdrawal at the end of 1968.

As early as October 1952, the Council had agreed on Geneva as the centre for the Laboratory, which was then confirmed in the Convention. The foundation stone was laid on 10 June 1955 at Meyrin, and the next day the Headquarters Agreement was signed with the Swiss Federal Council. At that time, the Laboratory comprised 40 hectares in the Canton of Geneva, upon which began construction of the two accelerators stipulated in the Convention, Article II, 3(a), namely:

i) a proton synchrotron for energies above ten giga-electronvolts (10^{10} eV);

ii) a synchro-cyclotron capable of accelerating protons up to approximately 600 million electronvolts (6×10^8 eV).

Meanwhile, the design and construction of the 600 MeV Synchro-cyclotron (SC) went ahead, and a first proton beam was produced on 1 August 1957. The Synchro-cyclotron has since supported a very vigorous programme of research in particle physics and nuclear physics. A major experimental facility for the study of short-lived nuclei (ISOLDE: Isotope Separator On-Line DEtector) was completed in 1967.

The first circuits of the Synchrotron by a proton beam were made on 16 September 1959, and full energy was achieved on 24 November. Since then the Proton Synchrotron (PS), operating at energies up to 28 GeV, has been a mainstay of the high-energy physics programme of Europe.

The decision by the Council to build intersecting storage rings associated with the Proton Synchrotron for research with colliding beams necessitated the extension of the Laboratory and, following approval by the Council in June 1965, an Agreement was signed on 13 September with the Government of France, together with a Lease Agreement putting at the disposal of the Organization a further 40 hectares of land in the communes of Prévessin and St. Genis-Pouilly adjoining the existing site. On 27 January 1971 the first proton–proton collisions in the Intersecting Storage Rings (ISR) were observed. A lively physics programme was immediately mounted at this machine, which was unique in the world.

Collaboration with non-member States has been actively pursued, and an Agreement was signed on 4 July 1967 with the State Committee of the USSR for the Utilization of Atomic Energy for a joint scientific and technical programme at the 76 GeV proton

synchrotron at the Serpukhov Institute of High-Energy Physics. The Agreement was extended in 1975 and again in 1983 by a Protocol which opened the possibility for Soviet teams to participate in experiments at CERN.

The setting up of a new Laboratory to house a proton synchrotron of 300 GeV energy, first discussed by the Council in 1963, required modifications to the original Convention. The Council, in December 1967, recommended to Member States the acceptance of the necessary amendments, and on 17 January 1971 the amended Convention came into force.

On 19 February 1971, 10 European States (Austria, Belgium, France, Germany (Fed. Rep.), Italy, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom) decided to participate in the 300 GeV Programme. They were joined in 1972 by Denmark.

It was agreed that the accelerator and the new experimental area in the north of the site should be built by CERN Laboratory II on land adjoining the existing Laboratory designated Laboratory I. A total of 412 hectares in France and 68 hectares in Switzerland was leased to the Organization, and building restrictions have been imposed on a further 509 hectares in France and 63 hectares in Switzerland.

The very large area involved and the open nature of the site—the accelerator has been built deep underground and only the few surface buildings are enclosed—required that the Agreement covering the legal status of the Organization in France be revised. The amendments were agreed by the Council in June 1972 and signed immediately afterwards on 16 June. The Lease Agreement for the new land in France was signed on 9 December 1972, as well as amendments to the first Lease Agreement (signed in 1965), so as to bring the two into concordance with each other. The "Contrat de superficie" for the new land in Switzerland was signed on 16 December 1974.

The eight-year long 300 GeV Programme was centred upon the construction of a proton synchrotron in a ring of 2.2 km major diameter. In June 1973, the Council approved a proposal that the ring should be filled with iron-cored magnets and that the construction schedule should be adjusted to allow the accelerator to reach a full energy of 400 GeV during the sixth year of the Programme so that research could begin at the end of that same year in the West Area.

The two CERN Laboratories were united into a single Laboratory on 1 January 1976.

The new 400 GeV accelerator, now called the SPS (Super Proton Synchrotron), reached its design energy for the first time in June 1976. The year 1977 was the first full year of operation of the SPS for experimental research, and its performance came fully up to expectations. The official Inauguration of the SPS took place on 7 May 1977.

The Twenty-Fifth Anniversary of the entry into force of the Convention was formally celebrated on 23 June 1979.

In 1980 a technique known as "beam cooling", invented at CERN, was used to produce high-intensity antiproton beams, and in 1981 intense antiproton beams were collided with proton beams, both in the SPS and the ISR, for the first time.

At the Council sessions of 25 June and 30 October 1981, all Member States voted in favour of the construction of Phase 1 of a large electron–positron colliding beam machine known as LEP with a design energy of 100 GeV per beam. The machine was to have a circumference of about 30 km, and the initial energy was fixed at 50 GeV per beam.

In 1983 Spain rejoined the Organization after an absence of 14 years.

On 13 September 1983 a ground-breaking ceremony marked the formal start of the civil engineering work for LEP. Also in 1983, a low energy antiproton ring (LEAR) was brought into operation providing antiproton beams of much greater intensity and better quality than ever available before.

In 1984 the Intersecting Storage Rings were closed down to liberate financial and manpower resources for the construction of LEP.

COUNCIL OF THE ORGANIZATION

STRUCTURE AND MEMBERSHIP

(as at 31 December 1984)

OBSERVERS
Poland
Turkey
Yugoslavia

OFFICERS OF THE COUNCIL

President Sir Alec MERRISON (United Kingdom)

Vice-Presidents Professor A C PAPPAS (Norway)
Dr J REMBSER (Federal Republic of Germany)

DELEGATIONS (two Delegates from each Member State)

Austria	Belgium	Denmark	France	Germany (Federal Republic of)	Greece	Italy	Netherlands	Norway	Spain	Sweden	Switzerland	United Kingdom of Great Britain and Northern Ireland
H E Mr G REISCH	Mr P LEVAUX	Mr P A KOCH	Professor J TEILLAC	Dr J REMBSER	H E Mr A PETROPOULOS	H E Mr M R PAOLINI	Mrs M C G HARTMANN	H E Mr M J HUSLID	H E Mr M D ALFONSO DE LA SERNA	Dr I VALLIN	Mr A CHAVANNE	Professor J F C KINGMAN
Professor W KUMMER	Professor J LEMONNE	Professor P OLESEN	Miss M A MARTIN-SANE	Professor W PAUL	Professor N ANTONIOU	Professor N CABIBBO	Professor J C KLUYVER	Professor A C PAPPAS	Professor C LOPEZ	Professor P CARLSON	Professor J P BLASER	Sir Alec MERRISON

SCIENTIFIC POLICY COMMITTEE

Chairman Professor D H PERKINS

Members
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Professor A N DIDDENS
Professor J D DOWELL
Professor P FALK VAIRANT
Professor S L GLASHOW
Professor C JARLSKOG
Professor E LOHRMANN
Professor L MAIANI
Professor G MORPURGO
Professor L B OKUN
Professor A SALAM
Professor K TITTEL
Dr R TURLAY

Ex officio members
the Chairman of the PS/SC Committee
Professor P G HANSEN
the Chairman of the SPS Experiments Committee
Professor L FOA
the Chairman of the LEP Experiments Committee
Dr G WOLF
the Chairman of the European Committee for Future Accelerators
Professor J SACTON

Also present
the President of the Council
Sir Alec MERRISON
the Chairman of the Finance Committee
Mr J ANDERSSON
the Director General
Professor H SCHOPPER

COMMITTEE OF COUNCIL

Chairman
the President of the Council
Sir Alec MERRISON (United Kingdom)

Members
the Vice Presidents of the Council
Professor A C PAPPAS (Norway)
Dr J REMBSER (Federal Republic of Germany)
the Chairman of the Scientific Policy Committee
Professor D H PERKINS (United Kingdom)
the Chairman of the Finance Committee
Mr J ANDERSSON (Sweden)

Council Delegates
Professor W KUMMER (Austria)
Mr P LEVAUX (Belgium)
Professor P OLESEN (Denmark)
Professor J TEILLAC (France)
Professor N ANTONIOU (Greece)
H E Mr M R PAOLINI (Italy)
Mrs M C G HARTMANN (Netherlands)
H E Mr M D ALFONSO DE LA SERNA (Spain)
Dr I VALLIN (Sweden)
Mr A CHAVANNE (Switzerland)
Professor J F C KINGMAN (United Kingdom)

Invited
Professor J SACTON
invited in his capacity as Chairman of the European Committee for Future Accelerators

Also present
Professor H SCHOPPER
Director General

FINANCE COMMITTEE

Chairman Mr J ANDERSSON (Sweden)

Members One Delegate from each Member State

PERCENTAGE CONTRIBUTIONS OF MEMBER STATES FOR THE FINANCIAL YEAR 1984

Member States	
Austria	2 37
Belgium	3 94
Denmark	2 10
France	20 64
Germany (Fed Rep of)	24 73
Greece	0 40
Italy	13 31
Netherlands	5 66
Norway	1 74
Spain	1 09
Sweden	4 05
Switzerland	3 87
United Kingdom	16 10

Internal organization as at 31 December 1984

Director-General
H. SCHOPPER

Office and Services of the Director-General

Directors of Research:
I. BUTTERWORTH
R. KLAPISCH

- Theoretical Physics Division
  Leader: M. JACOB
- Experimental Physics Division
  Leader: B. HYAMS
- Experimental Physics Facilities Division
  Leader: H. WENNINGER
- Data Handling Division
  Leader: P. ZANELLA

Director and LEP Project Leader:
E. PICASSO
Deputy: G. PLASS

- LEP Division
  Leader: G. PLASS

Technical Director
G. BRIANTI
Deputy:
G.L. MUNDAY

- Proton Synchrotron Division
  Leader: R. BILLINGE
- Super Proton Synchrotron Division
  Leader: B. de RAAD
- Technical Services and Buildings Division
  Leader: G. DROUET

Director of Administration:
R.F. HEYN
Technical Deputy:
A.J. HERZ

- Documentation Department (DOC)
  Leader: B. SOUTHWORTH
- Finance Department (FI)
  Leader: M. LAZANSKI
- Management Information Department (MI)
  Leader: C. ROCHE
- Personnel Department (PE)
  Leader: C.E. RUFER

Technical Inspection and Safety Commission (TIS)
Head: F. FERGER

Research Board

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Members: Directors, Leaders of Research and Machine Divisions, Chairmen of Experiments Committees, two outside members
Staff Association Observer
Secretary: Max FERRO-LUZZI

Management Board

Chairman: Director-General
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R. LÉVY-MANDEL and G.L. MUNDAY
Staff Association Observer
Secretary: W.O. LOCK

LEP Project

LEP Project Leader: E. PICASSO
Deputy to the LEP Project Leader: G. PLASS

LEP Management Board

R. BILLINGE	G. PLASS
F. BONAUDI	B. de RAAD
H. LAPORTE	H.P. REINHARD
E. PICASSO (Chairman)	L. RESEGOTTI
	W. SCHNELL

Ex officio Members:
Director-General, Technical Director

LEP Machine Advisory Committee

Chairman: G. VOSS (DESY)

External members:	Members from CERN:
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J. LE DUFF	I. BUTTERWORTH
G. REES	K. JOHNSEN
B. RICHTER	S. MYERS (Secretary)
G. SAXON	E. PICASSO
R. SIEMANN	G. PLASS
A.N. SKRINSKY	H. SCHOPPER
S. TAZZARI	

Ex officio Members:
Members of the LEP Management Board

Standing Concertation Committee

Members appointed by the Director-General:
G. BRIANTI
P. DARRIULAT
R.F. HEYN (Chairman)
R.N. MILLIGAN (Secretary)
C.E. RUFER
Members appointed by the Staff Association:
M. BORGHINI
M. DORAN (Vice-Chairman)
G. MAURIN
J.C. PERREARD
H. PINEY
Invited as Chairman of the Staff Policy Group:
G.L. MUNDAY

Introductory Review

H. Schopper

The discovery of the W and Z^0 produced in proton–antiproton collisions made 1983 an outstanding year in the annals of CERN. In 1984 the far-reaching importance of that discovery received recognition through the award of the Nobel Prize in Physics to two leading scientists at CERN. This highest honour in the world of science was bestowed on both Carlo Rubbia, who made the crucial proposal and was the leader of the decisive experiment, and on Simon van der Meer, who invented the technique and planned the source of antiprotons which was essential to produce proton–antiproton collisions at the highest energies ever achieved in a laboratory.

The Nobel citation for the first time explicitly recognizes the growing importance of 'big science' by stating that the award was made 'for their decisive contributions to the large project which led to the discovery'. Thus the honour is shared also by the team who prepared and ran the complex experiment, by the dedicated personnel who ensured the consistently high levels of machine performance and, in a wider sense, by the whole of CERN.

What better way of crowning the 30 years of the Organization's existence celebrated in September 1984! The 30th Anniversary of the ratification of the CERN Convention was attended by many personalities who had played an important role in the creation of a laboratory whose size and stature in 1984 they could not have imagined in the pioneering days of the fifties. The ceremony was honoured by the presence of

Figure 1—Carlo Rubbia (left) and Simon van der Meer, awarded the 1984 Nobel Prize for Physics, acknowledge the cheers of their colleagues. (CERN-523.10.84)

Figure 2—At the ceremony on 21 September marking the 30th Anniversary of CERN, H.M. King Juan Carlos of Spain (centre) listens to the Nobel Laureate I.I. Rabi who in 1950 launched the creation of CERN. With him are (left to right): P. Aubert, Swiss Federal Councillor; Sir Alec Merrison, CERN Council President; H. Schopper, CERN Director-General; H. Curien, French Minister for Research and Technology; and P. Brooks, UK Under-Secretary of State for Education and Science. (CERN-691.09.84)

the King and Queen of Spain, a most welcome visit and a symbolic gesture marking the re-entry of Spain into the Organization.

A Rich and Varied Research Programme

According to its tradition CERN is serving a large community of scientists predominantly from its 13 Member States. Because of the uniqueness of some of its facilities CERN is attracting ever more scientists from all over the world, e.g. from the USA, USSR, Japan, Israel, Canada and China. These researchers, in total about 2500, came from 195 universities or national laboratories and they work peacefully together in collaborations usually comprising several nationalities. Although the main emphasis of the research programme is on elementary particle physics at high energies, a considerable effort is made to support a varied research programme covering also nuclear physics, spectroscopy and even some ancillary activities in chemistry, medical applications and detection of gravitational waves.

About 350 physicists are catered for by the SPS in its proton–antiproton collider (Sp$\bar{p}$S) mode, whereas somewhat fewer than a thousand were engaged in fixed-target experiments when the SPS functioned as a proton accelerator. The available operating hours of the SPS per year are shared almost equally between these two operating modes. The complexity of the experiments has the consequence that the effort needed to analyse the data turns out to be nearly as important a limitation for the experiments than beam time. LEAR, the Low Energy Antiproton Ring, serves 16 experiments with 325 participants while the very first of the CERN accelerators, the SC, supplies the particle beams to the ISOLDE isotope separator, and to groups working on muon spin rotation (μSR) spectrometry and ion interactions, totalling over 150 experimentalists. Several hundred of these physicists already engaged at CERN can also be found among the 1000 now preparing very actively the four large experiments for the future LEP Collider.

This research programme together with necessary improvements of some facilities and the construction of the LEP project are carried out with an essentially constant staff and budget. This demonstrates that elementary particle physics is not consuming ever larger resources, as is often asserted in public, but on the other hand it implies, that very sharp selection criteria have to be applied and difficult choices have to be made when establishing the programme. This requires considerable flexibility, motivation and cooperation both from the staff of the laboratory and the outside users. But it also implies that the field is full of vigour and vitality, and the continuation of activities merely because of inertia cannot be tolerated.

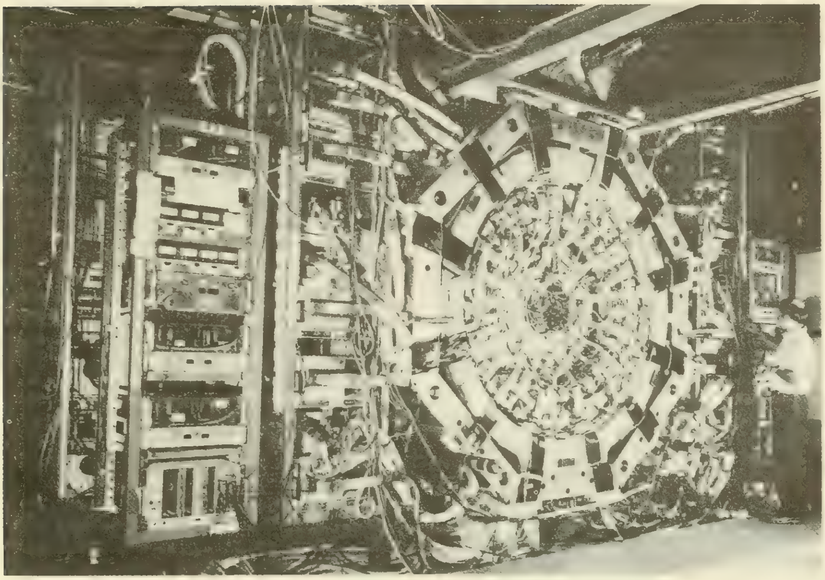
Performance Records Beaten

A sound experimental programme can only be founded on a consistently high level of accelerator and equipment performance. Beam time is, of course, always in great demand by the physicists, and therefore the periods allotted for machine development necessary to improve the characteristics of machine operation had to be kept to a minimum. Nevertheless it became possible to beat past records, for instance, by raising the SPS beam intensity from 2.6 to 3.2×10^{13} protons per pulse, mainly by increasing from 10 to 14 GeV the energy of particles transferred to the SPS from the PS. The latter has to undergo a continuous process of rejuvenation in order to assure its reliability and to improve its operational efficiency.

Examples are a new computer-operated control system and a new pre-injector in which the conventional Cockcroft–Walton generator has been replaced by a RF quadrupole system which not only focuses, but also accelerates the particle beam. The exploitation of the PS/SPS complex has been rendered much more efficient thanks to the adoption of only one period per year in either its fixed-target mode of operation or as Sp$\bar{p}$S Collider. The hours scheduled for physics in 1984—5966 for the PS complex, 2757 for the SPS fixed-target experiments, 1974 for the Sp$\bar{p}$S and 3932 for the SC—are proof of an unequalled degree of utilization of facilities to cover a wide range of research.

The improvement programme of the Sp$\bar{p}$S, approved in 1983, is well under way. It should be recalled that the Antiproton Accumulator (AA) originally conceived for an annual 1000 hours of operation is now required for 5000 hours per year to supply the antiproton needs of the Collider and of LEAR. By a number of steps already accomplished, the number of available antiprotons was increased and the energy of colliding particles raised from 540 to 630 GeV. In conjunction with other measures this produced a record number of p$\bar{p}$ collisions in terms of the total integrated

Figure 3 — The ASTERIX detector at the LEAR Low Energy Antiproton Ring, successfully used for the study of proton–antiproton interactions at rest in a hydrogen gas target. (CERN-399A.09.83)



luminosity. During the period of Sp$\bar{p}$S operation between September and the end of 1984 the figure reached 395 nb^{-1} as against 153 nb^{-1} for the 1983 runs. The improvement programme will culminate in 1987 with the completion of an additional antiproton collector ring, ACOL, surrounding the existing AA ring and capable of increasing the intensity by about an order of magnitude.

The suggestion of operating the Collider at the SPS maximum of 450 GeV per beam has been put to the test. The limitations imposed by power supplies and cooling necessitate pulsed operation, so that particles collide periodically at 450 GeV and then descend to 100 GeV. Preliminary trials with protons have been successful, giving a beam lifetime of several hours, so that such a complex mode of working may become feasible.

The operation of the LEAR storage ring which provides very pure and intense antiproton beams at very low energies could be considerably improved. It has become possible to run LEAR for 24 hours instead of only 12 hours per day, and a way has been found of syphoning off a small amount of antiprotons from the bulk of them stacked in AA and destined for the Sp$\bar{p}$S Collider, in order that LEAR may be run in parallel with the Collider. These improvements will help to meet the demands for more beam time by the users of this youngest of CERN facilities, which is unique and has proved to be very reliable in its first full physics runs at 300, 600 and 1500 MeV/c with finely controlled spills of about an hour's duration.

A Fruitful Year for Physics

It is obvious that, following the discoveries in 1983, interest remains very great in the new results obtained at the Collider during the last quarter of 1984 since here a so far unexplored energy range is being

investigated. The 'express analysis' of what may be termed 'simple' events, such as the production of W and Z^0 bosons, by experiments UA1 and UA2 has already yielded nearly 150 W decays as against the six or so at the time their discovery was confirmed. Twenty new Z^0 decays into electron pairs were found. For other forms of decay and the more complex events the analysis will take somewhat longer. The t quark with a mass of around 40 GeV has again made an appearance in the UA1 data. Particularly interesting is a type of event in which hadron showers are produced in one direction and the corresponding 'missing' energy is carried in the opposite direction by an invisible particle, a neutrino, perhaps, or one as yet unknown, manifesting 'supersymmetry', a theoretical concept unifying the families of fermions and bosons. More time will be needed for a proper evaluation of the significance of such events in the new data samples.

It is clear that CERN will remain fully competitive in $p\bar{p}$ physics until the end of the present decade with detectors duly upgraded to match the increased intensities resulting from the addition of ACOL.

From the wide range of results obtained by fixed-target experiments I can just mention the work of the European Muon Collaboration (EMC). Their systematic investigations of muon scattering from protons and nuclei have revealed a phenomenon now known as the EMC effect. A pronounced difference exists between scattering from free protons and that from protons bound in nuclei. This effect has been confirmed and additional information could be obtained by investigating specific reaction channels, e.g. those involving the production of J/ψ particles. Such investigations are greatly helping to clarify our understanding of the nucleus.

It is not only through massive experimental apparatus run by large groups that very useful results can be obtained. A few people backed by little, but specific, technical effort and much ingenuity can be quite successful too. A small multinational team has directly measured neutral-pion lifetime—of the order of 10^{-16} s—to an accuracy greater than previously considered possible. Their inspired use of synchrotron radiation to eliminate unwanted electron background signals and the development of a small mechanical device built to the highest standards of the watchmaker's art were instrumental in keeping the measurement errors so low.

Many interesting results have also come from the low-energy end of the spectrum. The new facility LEAR has opened a mine of information, for instance through the study of antiprotonic atoms, a means of atomic spectroscopy of the highest quality. The important role of the SC, the first accelerator of CERN, in serving a very enthusiastic and enterprising community of physicists should not be forgotten. The quite unique isotope separator ISOLDE, which has already helped to reveal many unfamiliar features of nuclear structure, is becoming even more versatile with the aid of laser beams used for the creation of excited atomic states. A new version, ISOLDE 3, now under construction, will go into action in 1986. In parallel with this almost traditional research at the SC, a number of small groups are carrying out a novel programme of spectroscopy based on the effect of muon spin rotation. The technique has proved very powerful in several domains of physics and chemistry, such as the investigation of magnetic properties, isotope effects, radiation damage, with particular attention also to substances of biological interest. This activity will be continued at CERN where the technological expertise on the requisite low temperatures, high pressures and refined detectors is available.

LEP Construction and Experiments

The project of constructing LEP has clearly passed the phase when paperwork predominated and has entered the 'hardware' stage when buildings old and new on the CERN site are being readied to receive a rising tide of manufactured components. All technical challenges so far have been met, many of the prototypes of the machine components have passed their tests with flying colours and series production has commenced in several instances.

As regards the LEP injector system, the buildings to house the linacs (LIL) and the Electron Positron Accumulator (EPA) are ready, and sections of the linac are being installed. Next in line, the necessary modifications to the PS and SPS have reached the testing stage of some of the components specially developed for the purpose. The design of the shielding against synchrotron radiation is proceeding and that of the transfer lines to LEP has been largely completed. It will be possible to re-use a considerable number of ISR magnets for the new tasks.

As for the LEP main ring, series production of the laminations and dipole magnet cores is well under way. Getting on to 200 cores have been cast and delivered to CERN, and tests on the first batches have

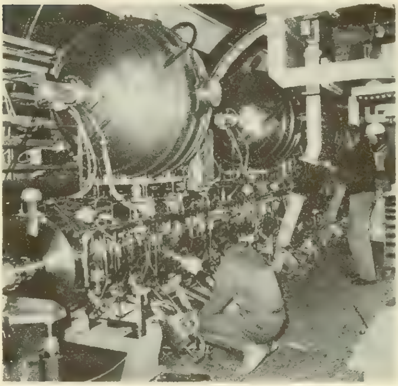
Figure 4 — The 16 coupled-cavity test string being installed using the first of the ambient temperature, copper, accelerating and storage cavities manufactured by European Industry. (CERN-x534.01.85)

Figure 5 — The body of one of the tunnelling machines on the site prior to being lowered down an 82 m deep shaft before starting to bore the 3.76 m diameter tunnel of LEP, the Large Electron-Positron ring now under construction. (CERN-459.01.85)

proved satisfactory. With regard to the RF accelerating system, series production of the klystrons and of several other components has started and a number of complete coupled-cavity assemblies have been finished.

The planning has been sufficiently flexible to cope with certain delays in some civil engineering operations so that the aim of completing the project by the end of 1988 stands. After having committed about 2/3 of the total cost of the project, it is gratifying to state that the expenditure on materials and components remains well within the limits of the original estimates.

Progress in the preparation of the four approved experiments has been truly impressive. These operations are carried out in over 100 institutes and involve some 900 physicists in the Member States and about 200 elsewhere, backed as they are by numerous technicians in their various workshops. Much has already been accomplished on the basis of prototype development and testing, and several of the development 'milestones', set by the LEP Experiments Committee



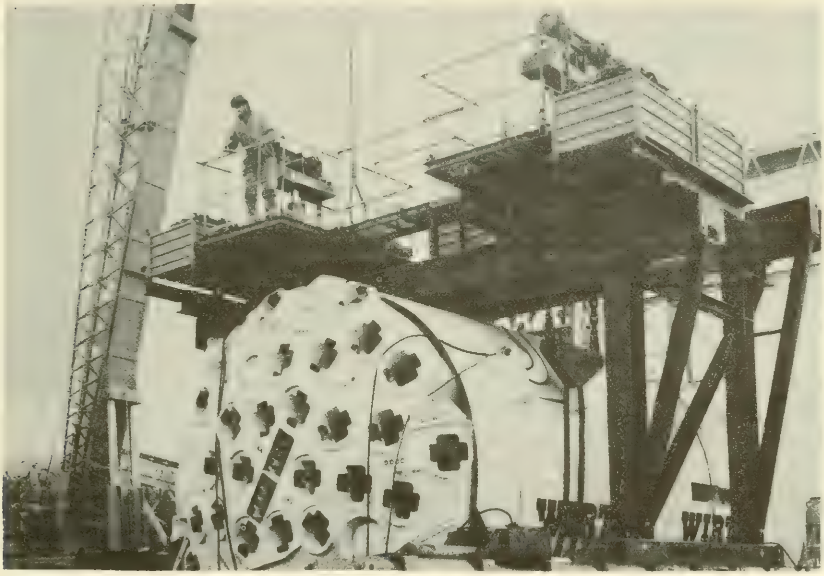
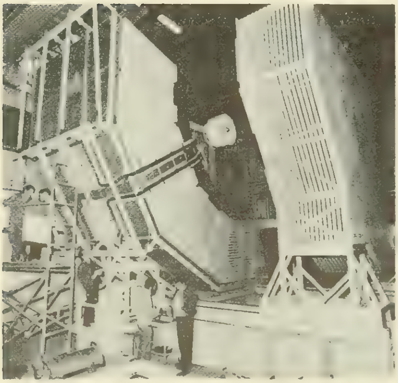


Figure 6—Full-size mock-up of one quadrant of the detector for ALEPH, one of the four major experiments being prepared for LEP. (CERN-083.03.85)



(LEPC) which assesses technical progress, have been met by the collaborations. The actual performance has, in some cases, turned out to be even better than envisaged in the original proposal. In the meantime many of the final components have been ordered or are being manufactured. The fact that the total cost of these experiments approximates 340 MSF, with a CERN contribution of 60 MSF and about 1/3 of the total cost from non-Member States, illustrates the novel character of these experimental ventures of the future, which calls for quite a new form of coordination and control. Thus the progress of expenditure by the various groups and laboratories is monitored by financial review committees for each experiment.

The LEP design has been optimized for beam energies of about 100 GeV, well above the Z^0 production peak, and the bending magnets are capable of handling energies up to 125 GeV.

To push the initial energy of 50 GeV per beam to the design energy it will be necessary to upgrade the accelerating RF system which has, above all, to compensate the losses due to synchrotron radiation. It is planned to realize this upgrading with superconducting cavities instead of the normal copper cavities. A vigorous development programme for this new technology is carried out at CERN and very encouraging results have recently been obtained. It is foreseen to have a few of these cavities in the LEP beam at turn-on in order to gain experience about their behaviour in an operating accelerator.

In order to exploit in the most efficient way the large investments being put into the civil engineering and the infrastructure existing at CERN, the possibility of placing a second ring (e.g. for protons and/or antiprotons) into the LEP tunnel had been considered already at the time of project approval. Since according to experience lead-times are very long and new magnet technologies might have to be developed, preliminary studies for various options of such a hadron collider in the LEP tunnel were started in collaboration with ECFA.

Organizational and Administrative Matters

Since staff is the most valuable asset of a laboratory and since some important problems concerning personnel policy became apparent, more attention has been and will be devoted to staff policy. Indeed the coming years will be decisive for long-term personnel policy. First of all, the number of retirements each year will rise rapidly in some four or five years from now. Careful planning will be required in order to have a smooth transition from the present situation of very few retirements. Then the whole question of employment conditions and recruitment policy will need to be carefully examined and reviewed in the light of the changing overall economic situation. Associated with these topics are a number of problems related to the pension fund, including the need to find substantial sums of money from 1990 onwards to pay the Organization's share of the four steps of the complementary pensions scheme. Then the whole question of the relations of CERN with industry will have to be critically examined, leading perhaps to a change in policy whereby much more work, including design work, is contracted out to industry. This will probably imply a reduction and/or restructuring of some of the basic CERN services. Lastly, the change-over from the construction phase of LEP to the operational phase will also bring problems, and a re-adjustment of the staff structure may well be necessary.

To attack all these questions, one needs the proper instruments. In this respect 1984 was an important year when two essential advances were made on the personnel front. First of all, for the first time a formal tripartite committee (with representatives of the Member States, the Management and the Staff Association) was set up, reporting directly to Council, namely the

Consultative Committee on Employment Conditions (CCEC). Its value was immediately made evident by the agreement in principle reached by Council in October on the Fourth Step of the Complementary Pensions Scheme.

Secondly, an internal Staff Policy Group was established. The group has already tackled such topics as staff appraisal and career paths as well as looking into some organizational aspects of personnel matters.

Further steps will be taken during 1985 to strengthen other aspects of personnel management in the Organization in order to make the best and most efficient use of the human resources of the Laboratory.

Outlook

CERN is presently in a very successful phase.

With the $p\bar{p}$ improvement programme, with LEP (initial stage and upgrading) and later options in the LEP tunnel, CERN has all prospects from the immediate to the more distant future to remain in the forefront of world high energy physics. Of course, the production of excellent scientific results will remain the main aim of the laboratory.

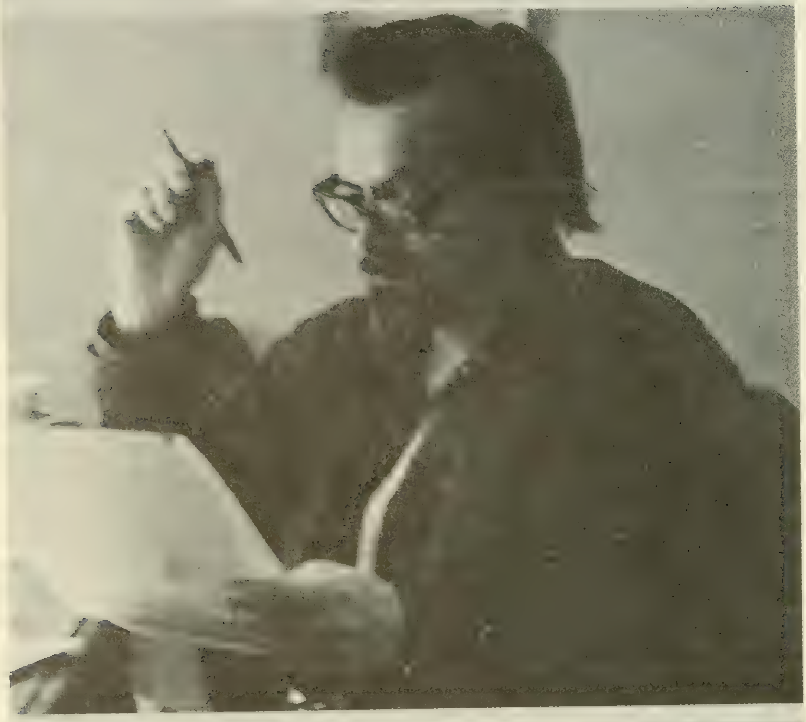
However, one should not forget some other benefits which emerge from the activities of CERN. International collaboration has been an essential element during the history of CERN, right from the beginning. With the preparations for the LEP experiments this cooperation has reached a new quality, embracing the whole globe, and will certainly continue to contribute to a better mutual understanding of scientists from different countries and different social and political systems.

For quite some time it has been accepted that CERN is a centre of advanced technology giving many incentives to industry. This has recently been confirmed by a study of the economic utility of contracts adjudicated by CERN to industry.

Last but not least, it is more and more recognized that CERN offers excellent opportunities for training, not only to scientists but also to technicians. As a consequence some of the training programmes have been intensified, sometimes on the basis of bilateral agreements with Member States.

CERN will endeavour to continue to render its service to the Member States and to society in general, in the form of scientific, cultural, human and technological contributions.

Theoretical Physics Division



Vladimir Jurko Glaser, 1924–1984
(Photo Nina Glaser)

Theoretical Physics Division

The November telephone list of the CERN Theory Division had 105 names—the August list had 140. In addition there were, as always, many visitors not staying long enough (at least one month) to be so listed. There are only 21 Staff physicists.

During the year, 292 preprints were produced in the Division. They were spread over the whole range of elementary particle theory, and even a little further, but only a few main themes will be mentioned below.

Unified Theories

Theoretical physicists are increasingly optimistic about the possible production of a theory unifying the strong, electromagnetic, weak, and gravitational interactions. The most promising candidates at this time are supergravity and Kaluza-Klein theories.

The excessively high degree of symmetry shown by such theories has somehow to be spontaneously broken. In this connection, supergravity models with 'flat potentials', introduced at CERN last year, were further developed. A remarkable intuitive explanation was found for the existence of non-compact global symmetries in extended supergravities, as required for the flat potential. The construction of the full $N = 2$ Yang-Mills supergravity Lagrangian and the study of its mathematical and physical implications were vigorously attacked. Some versions of $N = 2$ are of particular interest in that the desired flatness of the potential emerges automatically. The possibility of 'no-scale' models, in which all scales other than the Planck mass are determined by the dynamics, was further explored, with encouraging results. The possibility of decoupling local and global SUSY-breaking scales may prove to be important. One such model, with almost massless gravitinos, gives a natural resolution of the strong CP problem, with θ_{QCD} dynamically relaxed to zero. As regards weak CP violation, the standard model seems to have difficulty with the observed bottom-quark lifetime and top-quark mass around 40 GeV. The supersymmetric version was worked out in great detail; it was found to be problem free, and to have interesting consequences for experiments in preparation at CERN and elsewhere.

The study of supersymmetric theories at finite temperature raised the possibility of symmetry not being restored at very high temperature, which would have implications for the early Universe.

In Kaluza-Klein theories, space is initially given extra dimensions. They are supposed to curl up somehow to have very small extension, and so appear phenomenologically as internal rather than external degrees of freedom of particles. The extra components of the gravitational field then appear as the gauge and other fields of elementary particle physics. Considerable progress was made in seeing how the 4-dimensional $N = 8$ supergravity is embedded in the 11-dimensional theory. And new results on spontaneous symmetry breaking were obtained.

Cosmology

There is now a strong interaction between elementary particle physics and cosmology. In particular, scenarios for the very hot early Universe bring into play the high-energy features of unified theories, providing a critical testing ground for such theories.

In this connection the 'flat-potential no-scale' supergravity models proved especially interesting. They produce naturally, at tree level, one of the outstanding unexplained features of cosmology—the vanishing cosmological constant. A flat zero scalar potential is obtained at tree level. Radiative corrections produce a minimum, determining dynamically the breakdown scale m_W of the Glashow-Salam-Weinberg symmetry. A value of the cosmological

constant of order m_W^4 then appears, unfortunately not zero but much smaller than the otherwise natural value $m_W^2 m_P^2$. These models have been extended to produce the early exponential inflation which is at present thought to account for the subsequent large-scale homogeneity and isotropy of the Universe. This inflation also serves to reduce the density of monopoles, which would otherwise be a problem. Even with inflation the gravitinos, with mass of order m_W, regenerated during the 'reheating' phase, tend to provide an excessive energy density. But this is avoided in a subclass of these models in which the scale of supersymmetry breaking is related to the mass, not of gravitinos, but of gauginos (supersymmetric partners of gauge bosons).

Some work was also done on the emergence of large-scale features — galaxies and clusters — as possibly triggered by unstable neutrinos. And experimental ways were suggested for the detection, in cosmic rays and in the Earth's crust, of the strange matter of Witten, containing about as many s quarks as u and d, that might be left over from the confining transition.

Collider Physics

Much of the work of the Division centred on the physics produced by present and future CERN colliders.

The theory of W and Z production in present and future colliders was worked out in great detail — the most thorough analysis yet made. The formalism was checked against ISR data on lepton pair production, with full agreement. Within the accuracy of the data no intrinsic quark transverse momentum was required, leaving the QCD scale Λ as the only parameter. In connection with the transverse momentum distribution of W and Z at the CERN $p\bar{p}$ Collider, conjectures about the summation of leading logs were established, and the resulting theory was shown to agree well with the data. A theory of hadron activity associated with W and Z production did not suggest notably stronger activity for Z than for W, despite hints from preliminary, low-statistics data that this might be so experimentally.

Preliminary indications for diffractive t-quark production in UA1 led to a theoretical analysis of this process. In connection with UA2 data, the theory of probability distribution over jet number was developed, with the aim of extracting the QCD coupling constant. In connection with the ISR gas jet experiment, in which antiprotons collide with hydrogen atoms, a detailed analysis was made of the formation and decay of charmonium states, which will be of great value in the final analysis of the experiment. The possible production and detection of supersymmetric particles at the CERN Collider received particular consideration.

Much attention was given to the surprising one-jet events and hard photon decays of Z seen in the UA1 and UA2 experiments. Theories involving excited composite quarks, and others involving supersymmetry, were advanced. An interpretation of the 'mono-jet' events as involving squark–antisquark pair production seems very promising, with a mass of some 40 GeV for the squark — the supersymmetric partner of the quark. This would be the first phenomenological manifestation of supersymmetry.

A model was proposed for the expansion and hadronization of droplets of quark gluon plasma that might be produced in high-energy collision of hadrons and especially of nuclei. Comparison with existing experimental data was encouraging for a systematic search. The model has implications also for the quark-gluon-plasma to hadron-gas transition in the early Universe.

Many members of the Division participated in the study of the proposal to install a large hadron collider (LHC) in the LEP tunnel, and in the conference on this subject, which took place in Lausanne and at CERN in March. If supersymmetry is good, a flood of new particles should appear. Compositeness of quarks and leptons might show up. In particular, it was pointed out that the device, copiously producing charmed particles, would be a surprisingly powerful source of leptons, including muons and neutrinos, and maybe of the hypothetical photinos of supersymmetry. If leptons and protons are collided, the evolution of structure functions to much higher q^2 can be followed. Predictions for proton–proton and proton–antiproton elastic scattering in future higher-energy colliders were made.

Quantum Field Theory

Quantum field theory is the foundation for the whole of elementary particle physics. As well as applications to would-be realistic schemes, there is a continual effort to deepen understanding of the theory.

Anomalies — failures in higher order of symmetries holding in lowest order — were studied in space-times of arbitrary dimension. It has become important to do so because of the current interest in Kaluza–Klein theories, and because of relations between anomalies in different numbers of dimensions. A systematic classification in terms of group topology has been achieved.

In non-linear sigma models with hidden gauge symmetries, it was found that anomalies, at the quantum level, force reconsideration of the dynamical generation of gauge bosons.

The question of chiral symmetry-breaking in the supersymmetric extension of the Nambu–Jona-Lasinio model was analysed. Supersymmetry protects chiral symmetry, but with soft supersymmetry-breaking, spontaneous chiral symmetry-breaking appears, together with composite Goldstone bosons, for strong enough coupling.

It was investigated how in supersymmetric gauge theories the non-perturbative effects are able to generate non-trivial vacuum properties otherwise forbidden by perturbative non-renormalization theorems. The unconstrained instanton method emerged as a powerful and self-consistent approach.

For supersymmetric theories, a systematic method for the identification of stochastic variables (Nicolai mapping) was devised.

An argument was given for the equivalence of stochastic and microcanonical quantization in Euclidean field theory.

An analysis of gauge theory monopoles suggested that they can have fractional spin and intermediate statistics.

In connection with string theory, progress was made with the irreducible representations of the Virasoro algebra, and their applications for constructing new string models. And the construction and analysis of Liouville field theory suggested a whole new class of statistical models. It was established that the S-matrix of the Liouville field theory is trivial in the context of the D'Hoker–Freedman–Jackiw quantization.

Lattice Gauge Theory

Substantial effort was again devoted to the direct numerical simulation of gauge theories. This is greatly impeded by the limitations of present computers. Much insight and analysis are required in order to interpret the preliminary results.

In this connection the Monte Carlo renormalization group (the numerical approach to the real space renormalization group) was intensively studied. It permits the approach to the continuum limit to be handled in an economical fashion. The resulting beta function explained the unexpected scaling of the deconfinement temperature in pure SU(3) gauge theory. In that theory, definitive results for string tension were obtained.

The incorporation of quarks into the calculations remains at an exploratory stage. Comparison between Kogut–Susskind and Wilson fermions, in quenched approximation, showed disagreement by a factor of 2 for quark masses.

A definition of topological susceptibility in lattice QCD was shown to be perturbatively zero, and therefore suitable for Monte Carlo simulation. A practical definition for an integer-valued topological charge was proposed. One-loop perturbative calculations of Wilson loop expectation values were performed, giving the possibility of constructing improved variables that are less sensitive to lattice artefacts. By introducing appropriate collective coordinates, difficulties in applying perturbation theory to O(N) lattice sigma models were resolved.

Ideas have been put forward for a specialized computer which would be faster, and very much cheaper, than commercially available alternatives. A feasibility study is starting in collaboration with groups in the Member States.

Composite Systems

Hadrons are held to be composites of quarks, and it is speculated that quarks, leptons, and gauge bosons, might themselves be composite. So the dynamics of binding is of continuing importance.

The Shifman – Vainshtein – Zakharov sum rule technique was applied in a systematic way to quarkonia and gluonia. For the charmonium system it was argued that the large correction found for the $Q^2 = 0$ version of the method would be greatly reduced in the large Q^2 version. The SVZ method was applied also to hypothetically composite quarks, leptons, and gauge bosons. For composite weak bosons, a serious difficulty emerged — that of too strong coupling to quarks.

In the potential model, new bounds on energies and wave functions were presented. And a very elegant theorem on the ordering of levels in potentials was given. Comparison with the Coulomb case shows the Laplacian of the potential to be the controlling feature. The theorem has applications in nuclear and atomic, as well as in subnuclear physics.

Stimulated by evidence for the top-quark at UA1, a detailed study was made of the production and decay of toponium. If the mass is indeed about 82 GeV, toponium produced at LEP will be almost completely polarized, which will help in its identification.

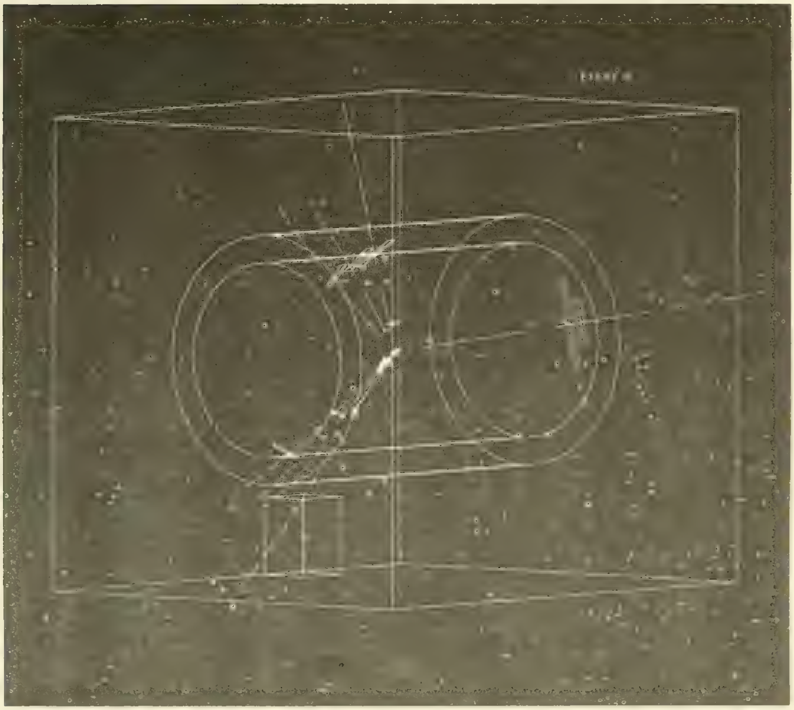
Corrections to pion low-energy theorems were evaluated in a systematic one-loop chiral perturbation theory; the improved theorems agreed very well with experiment.

Other Activities

The main roles of TH Division were, as always, original research and collaboration with the experimenters. Only a fraction of the year's research production has been mentioned above. The collaboration with experimenters seemed to us to go very well. The Division also has an educative role. Many members gave lecture courses — in the Division, in the CERN Academic Training Programme, at summer schools and winter schools, and at workshops — and a large number of individual talks were delivered, both in Europe and abroad. The Division also contributed, as usual, to the management of CERN, participating in the work of the various committees.

EP

Experimental Physics Division



Computer display of an event observed in the UA1 experiment.
This may be interpreted in terms of W^- production
with subsequent decay of the $W^- \rightarrow \bar{t}b$

$\rightarrow$ *jet*

$\rightarrow e^- \bar{\nu} b$

$\rightarrow$ *jet*

Experimental Physics Division

Introduction

The $p\bar{p}$ collider and the experiments around it have again operated successfully in 1984. Due to increased luminosity they have had more than twice as many $p\bar{p}$ interactions to investigate as in 1983.

Two exciting new observations have come from UA1: the finding of events with missing transverse energy exceeding 40 GeV accompanied by a single jet or single electromagnetic cluster. These cannot be well accounted for by known processes, and may herald the observation of totally new phenomena. Analysis of the data (and theoretical speculations) are proceeding vigorously.

A class of events has been observed that fits well with the expected characteristics of particles containing the yet undiscovered 'top' quark. If this explanation is confirmed it will establish the mass of the top quark to be in the range 30 to 50 GeV.

The $\bar{p}$ accumulator has also continued to act as a unique high-intensity source of low energy antiprotons for the low energy antiproton ring LEAR. Data have been accumulated on a wide variety of processes. To quote one with 'far-reaching' consequences—the measurement of the reaction $\bar{p}\,^4He \rightarrow {}^3He + X$ has shed light on the antiproton abundance in the early eras of our universe!

At the lower energy end of the spectrum of CERN's experimental programme the ISOLDE facility has discovered two new cases of the exotic radioactive decay mode giving the emission of ^{14}C nuclei.

This report describes many of the other results obtained in processes in the energy range of 540 GeV ($\bar{p}p$ collisions) to 0.01 eV (muon spin rotation). Brief mention is made of some of the technical activities on which this experimental programme depends.

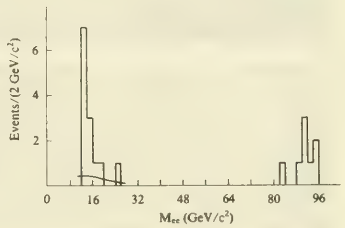
Proton–Antiproton Collider

Intermediate vector bosons

The analysis of data provided by the 1982 and 1983 runs of the Collider ($\sim$20 and 120 nb^{-1} integrated luminosity respectively) continues with the emergence of important new results from the two large collaborations, namely Aachen – Amsterdam – Annecy – Birmingham – CERN – Harvard – Helsinki – Kiel – London (QMC) – Padua – Paris (CdF) – Riverside – Rome – Rutherford – Saclay – Vienna – Wisconsin (UA1) and Bern – CERN – Copenhagen – Heidelberg – Orsay (LAL) – Pavia – Perugia – Pisa – Saclay (UA2).

Mass values obtained from leptonic decays of the $W^{\pm}$ and Z^0 have been refined, and are in good agreement with the expectations of the standard model. The width of the Z^0 is related to the total number of quark and lepton families; the width value obtained from a careful analysis of the few $Z^0 \rightarrow e^+e^-$ events available (Fig.1) and the ratio of the Z and W cross section allow UA2 to claim that with 90% confidence the additional number of neutrino generations beyond the three of the standard model is smaller than 17.

Figure 1 — Mass spectrum of identified $Z^0 \rightarrow e^+e^-$ decays together with lower mass e^+e^- candidates. The curve is the estimated background (UA2).



Search for new physics

Small samples of events from the UA1 and UA2 Collaborations have intriguing features which may be indications of exciting new physics. New data from the 1984 run are awaited to provide confirmation and understanding of the true nature of these effects.

For example the UA1 Collaboration have reported the observation of events where a missing transverse energy greater than 40 GeV is associated with a single jet or a single electromagnetic cluster. The transverse masses for these events are larger than those expected for W and Z^0 decays. An example of such

Figure 2—Example of UA1 'monojet': (a) a missing transverse energy of 59 GeV is balanced by a high energy jet (b) observed transverse energy flow.

'monojet' events is shown in Fig. 2. Interpretations of these events in terms of some new particle (e.g. the photino of supersymmetric theories) carrying away the missing energy are being entertained.

A search for the t-quark (top) needed to complete the third generation of quarks and leptons is being carried out by the UA1 Collaboration. They look for decays of a single W^+ or W^- into a top and a bottom quark where the top quark ($m_t > 22$ GeV/c^2) has a subsequent semileptonic decay, viz.:

$$W^+ \rightarrow t\bar{b} \qquad t \rightarrow \ell^+ \nu b \qquad \ell \equiv \text{(electron, muon)},$$

or $$W^- \rightarrow \bar{t} b \qquad \bar{t} \rightarrow \ell^- \bar{\nu} \bar{b}.$$

The signature for these events would be: two jets (b and $\bar{b}$ fragmentation) and an isolated lepton. At present six possible candidates have been identified, one of them is shown in the frontispiece. They are found to be consistent with the $W^+ \rightarrow t\bar{b}$ (or $W^- \rightarrow \bar{t}b$) decay. If this is indeed the case, then the mass of the top quark lies between 30 and 50 GeV/c^2. However more data are needed to confirm these conclusions.

The UA1 Collaboration have in addition to five muonic decays of the Z^0, several other interesting dimuon events which may indicate evidence for heavy flavour semi-leptonic decay. The most intriguing, shown in Fig. 3, has two lone muons with the same charge having large transverse momenta.

Radiative decays of the Z^0 ($Z^0 \rightarrow \ell^+\ell^-\gamma$, $\ell^\pm$ being an electron or a muon) have been observed both by UA1 and UA2. Their observation has triggered much interest since their yield seemed larger than that expected from inner bremsstrahlung processes.

Another intriguing result comes from the UA2 Collaboration which have found three unexpected events out of a sample of 190 events containing an electron candidate. In these possibly anomalous events a system of jets and an electron are observed in as-

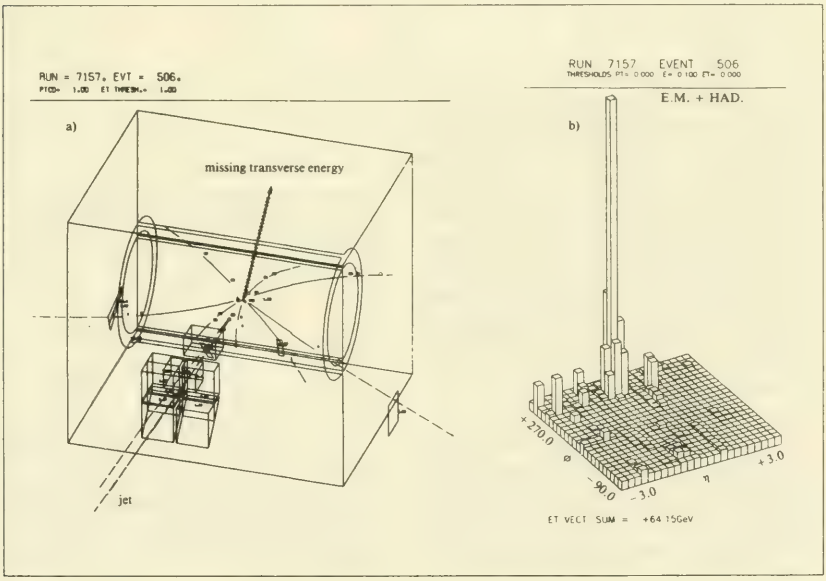
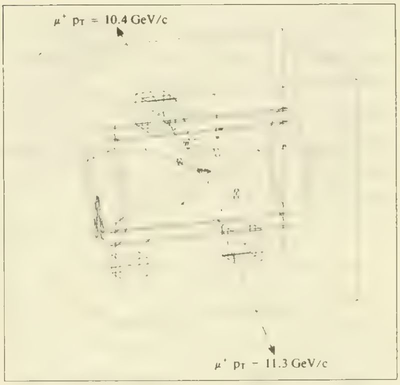


Figure 3 — UA1 event containing two positive muons with large transverse momenta. It is hard to interpret this event in terms of conventional processes.

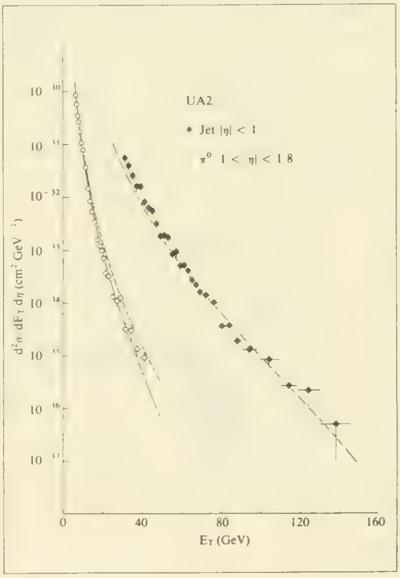
Figure 4 — Cross sections for inclusive jet and π^0 production. The curves are the predicted jet cross section at η (pseudorapidity) = 0 (-.-) and π^0 cross section at η = 0 (--) and at η = 1.4 (—) (UA2).

sociation with a large missing transverse momentum. These events are consistent with the production of massive $e\nu$ pairs associated with jets of large transverse energy. A possible interpretation is the associated production of W and jets.



Jet production

Collider data are a rich source of final states containing hadron jets from quark-quark, quark-gluon and gluon-gluon scattering. Their analysis has given a number of interesting results which have contributed to our understanding of QCD. They concern the proton structure functions, the nature of the parton-parton interaction and the fragmentation properties of hadron jets. An example, from the UA2 Collaboration, of the agreement between QCD-based calculations and the inclusive cross section both for jets and π^0's is given in Fig. 4.



Elastic scattering and total cross section

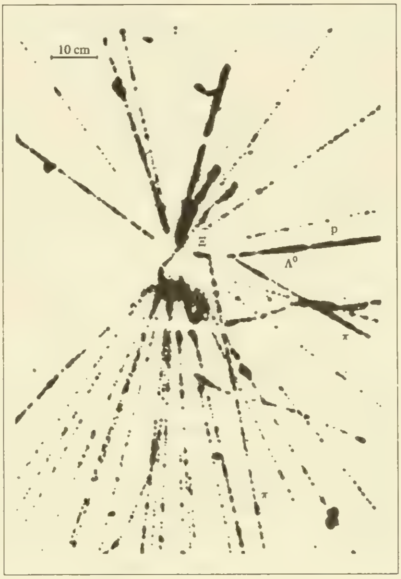
The Amsterdam - CERN - Genoa - Naples - Pisa Collaboration (UA4), have analyzed the data on elastic $p\bar{p}$ scattering and total cross sections collected during the 1983 special high-β run. The data show a change in slope of the elastic scattering t-distribution around $|t| = 0.14$ GeV^2 (Fig. 5). The total $p\bar{p}$ cross section at $\sqrt{s} = 546$ GeV is 61.9 ± 1.5 mb, i.e. ~ 50% higher than that found at the ISR. This rise is consistent with a $(\log s)^2$ behaviour which is the fastest energy dependence allowed by general principles. The ratio of elastic to total cross section is also significantly larger than at ISR energies. These observations indicate that at collider energies the proton has a larger size than at ISR energies and is more absorbing in the central core.

Streamer chamber studies

The Bonn - Brussels (Free University) - Cambridge - CERN - Stockholm Collaboration (UA5) continue the study of inelastic $p\bar{p}$ interactions using a large streamer chamber. They have studied the production of charged and neutral kaons and made a detailed study of charged particle multiplicities. The cascade decay $\Xi^- \rightarrow \Lambda^0\pi^-$, followed by $\Lambda^0 \rightarrow p\pi^-$,

Figure 5—Differential cross section of proton-antiproton elastic scattering at $\sqrt{s}$ = 546 GeV. The lines drawn are the results of simple exponential fits exp(bt) (UA4).

Figure 6—An example of the cascade decay $\Xi^- \rightarrow \Lambda\pi^-$, $\Lambda \rightarrow p\pi^-$ as observed in the UA5 streamer chamber.



has been observed for the first time at the Collider; an example of such an event is shown in Fig. 6. It is surprising that the observed ratio Ξ^-/Λ^0 (for p_T > 1 GeV/c) is substantially larger than at ISR energies.

ISR Programme

pp and p$\bar{\text{p}}$ interactions

This year saw the last operation of the ISR. From now, therefore, the ISR Programme will consist of the analysis of the data already acquired.

The CERN - Michigan State - Oxford - Rockefeller Collaboration (R110) have measured the cross section for the production of e^+e^- pairs with masses above the Υ mass at $\sqrt{s}$ = 62.3 GeV (Fig. 7). The data are consistent with the scaling hypothesis when compared with lower $\sqrt{s}$ data. The large observed values of the transverse momentum of the pairs ($\langle p_T \rangle$ = 2.50 ± 0.25 GeV/c) indicate contributions from higher order diagrams other than the Drell-Yan mechanism.

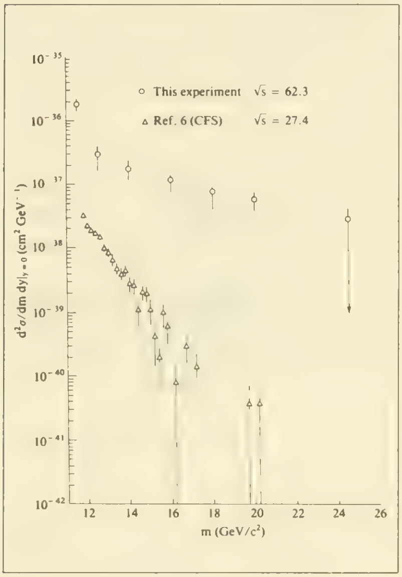
The same collaboration present evidence for the jet-like nature of most events with high transverse energy produced in pp collision at $\sqrt{s}$ = 62.3 GeV.

The Annecy - CERN - Dortmund - Heidelberg - Paris (CdF) - Warsaw Collaboration (R416) and the Ames Lab. - Bologna - CERN - Dortmund - Heidelberg - Warsaw Collaboration (R419), using the Split Field Magnet (SFM), have continued their study of deep inelastic events and comparison with parton hard scattering and fragmentation models. They give evidence that the fragmentation of scattered quarks is mainly responsible for the production of $\pi^\pm$ and K^+ at high transverse momenta while the production of K^-, which do not have any valence quark in common with the colliding protons, is due to the fragmentation of scattered gluons. A large relative yield of high p_T protons is observed which is interpreted as the result

Figure 7—The cross section for e^+e^- pairs above the Υ at $\sqrt{s}$ = 62.3 GeV from R110 compared to Fermilab results.

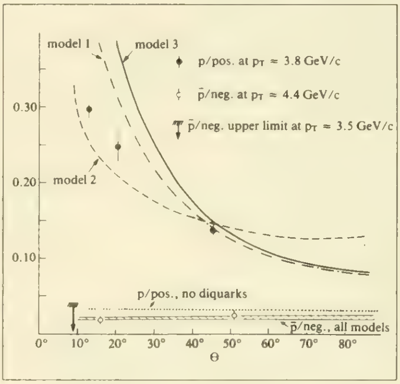
Figure 9—Residual γ/π^0 ratio, after background subtraction, versus transverse momentum for proton-proton and proton-antiproton interactions. The two curves are predictions for pp (solid line) and $\bar{p}p$ (dashed line) collisions (R808).

Figure 8—Observed dependence of the relative proton and antiproton yields at fixed p_T on the polar angle (R416/R419). The curves are predictions of models with and without diquark scattering and fragmentation. The antiproton fractions are well reproduced by all models while diquarks (model 1, 2, 3) seem necessary to describe the proton fractions.



of the hard scattering of diquarks and of their fragmentation into protons (Fig. 8).

The Brookhaven - Cambridge - CERN - Copenhagen (NBI) - London (QMC) - Lund - Pennsylvania - Pittsburgh - Rutherford - Tel Aviv Collaboration (R807), using the Axial Field Spectrometer (AFS) have continued the study of production and fragmentation of jets, which have been shown to dominate the event structure for sufficiently high transverse energies.



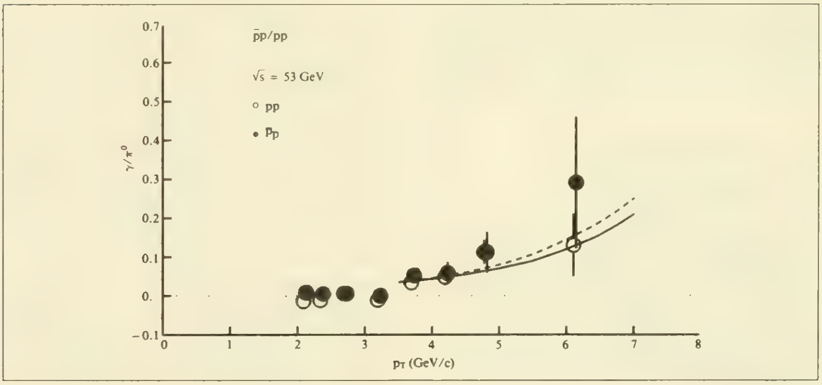
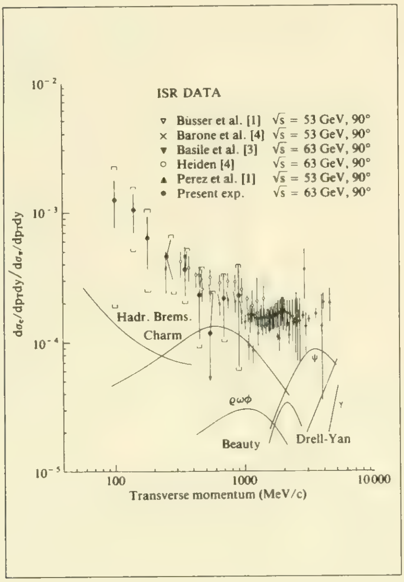


Figure 10—The ratio of e^+/π^+ as a function of p_T. Also shown are calculated contributions to the signal from known sources (R808).

Figure 11—$K^0K^\pm\pi^\mp$ mass spectrum from the (mainly) diffractive reaction $pp \to ppK^0K^\pm\pi^\mp$. Clear signals are present in the D(1285) and in the E/iota regions (R608).



An attempt has also been made to measure the ratio between the abundances of two and three-jet events and hence the strength of the QCD coupling which is estimated to be $\alpha_s = 0.17 \pm 0.02 \pm 0.05$.

Another AFS Experiment, by the Athens–Bonn–Brookhaven – CERN – Moscow (LPI + EPI) – Novosibirsk – Pisa Collaboration (R808), have presented data on direct photon production in pp and $p\bar{p}$ collisions. A significant prompt photon signal is observed in the p_T region between 3–6 GeV/c (Fig. 9). The same Collaboration have also studied the inclusive production of electrons down to 100 MeV/c transverse momentum. An excess of low p_T electrons is observed (Fig. 10), which is not explained by known processes.

The CERN – Clermont-Ferrand – Saclay – UCLA Collaboration (R608) are studying the $K^0K^\pm\pi^\mp$ system produced in the reaction pp $\to$ pp $K^0K^\pm\pi^\mp$. Two clear peaks (Fig. 11) are observed at the D(1285) mass and in the E/iota (1430) mass region. A spin parity analysis is being performed to find out whether the signal in the E/iota region is due to the E meson ($J^P = 1^+$), which is considered to be a $q\bar{q}$ state, or to the $J^P = 0^-$ gluonium candidate observed in $p\bar{p}$ annihilation and in the radiative decay of the J/ψ. Other results obtained by the Collaboration are a comparison of elastic scattering cross sections in pp and $p\bar{p}$ reactions, and a determination of the inclusive Λ^0 polarization.

The CERN – Naples – Pisa – Stony Brook Collaboration (R210) have completed the analysis of the

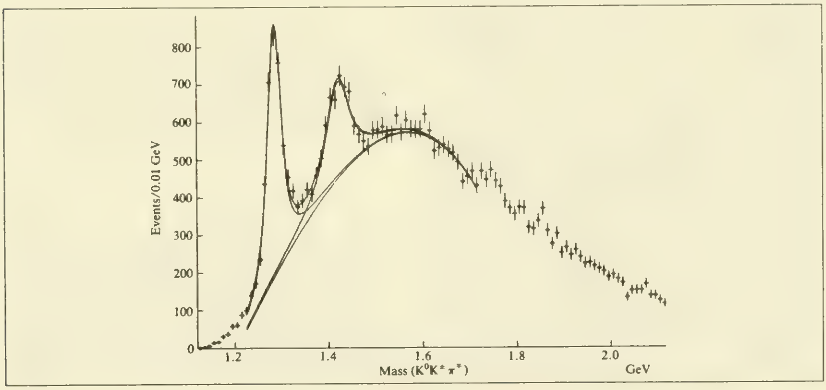
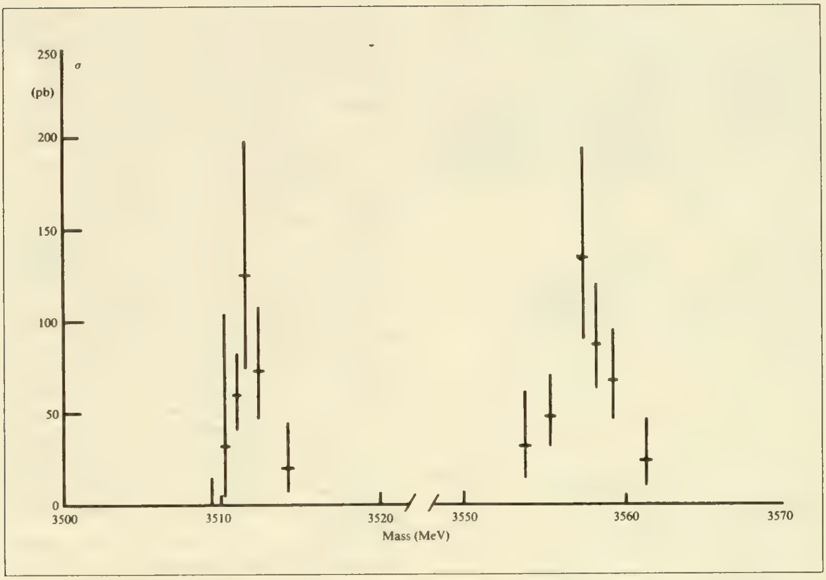


Figure 12—Excitation function (R704) of the χ_1 and χ_2 states from the decay $\chi \rightarrow J/\psi + \gamma$, $J/\psi \rightarrow e^+e^-$.



total cross section data for pp and p$\bar{p}$ at $\sqrt{s}$ = 30.6, 52.8 and 62.7 GeV. A simultaneous fit of pp and p$\bar{p}$ data indicates a $(\log s)^2$ behaviour of the two cross-sections.

The Bologna - CERN - Frascati Collaboration (R421), using the SFM continue the study of low p_T multiparticle final states in pp reactions, using the method of removing leading protons to define the effective energy available for particle production. The charged particle multiplicity distributions at ISR energies are found to scale with the effective energy. A comparison with e^+e^- data shows that the multiplicity distribution measured in e^+e^- interactions is narrower. Extrapolation to collider energies gives good agreement with the charged multiplicities measured by UA5. The same collaboration is now processing the data from Experiment R422 to study the associated production of heavy flavour states using the SFM.

The Annecy - CERN - Genoa - Lyon - Oslo - Rome - Turin Collaboration (R704) are studying the formation of charmonium states in the collision of antiprotons with a hydrogen-gas jet target in the ISR ring. The experiment has detected the radiative decay of the charmonium states χ_1, χ_2, (Fig. 12) and η_c formed in the p$\bar{p}$ collision and has made a search for the yet unobserved $^1P_1$ (S = 0, L = 1) charmonium state. The analysis of these data is in progress.

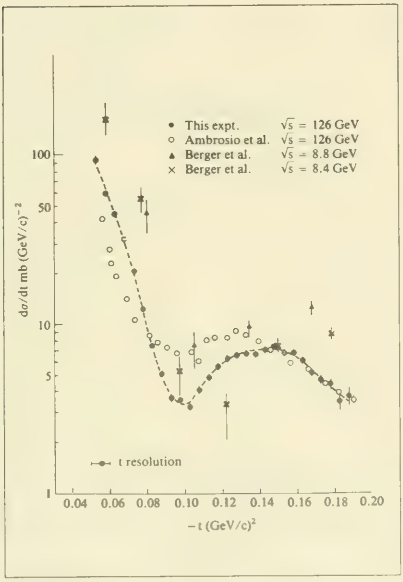
Light ion interactions

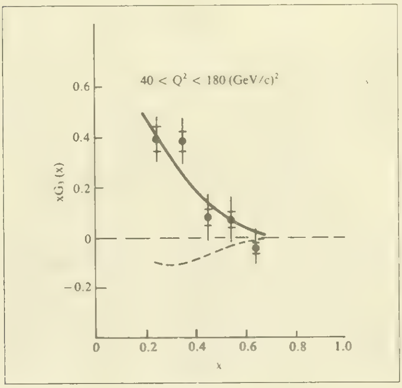
The analysis of data from the past α-α, d-d and p-α runs is being carried out by several collaborations.

The BNL - CERN - Michigan State - Oxford - Rockefeller Collaboration (R110) have measured the total neutral energy spectra in the central region of αα, dd and pp interactions at $\sqrt{s_{NN}}$ = 31 GeV. The shape of the αα spectrum up to 17 GeV is explained by representing an αα collision as a superposition of four independent nucleon-nucleon collisions. Beyond 17

Figure 13 — The αα elastic differential cross section (R807). The dashed curve is a guide for the eye. Also shown for comparison are results from earlier experiments.

Figure 14 — The interference structure function $xG_3(x)$. The solid line represents the structure function $F_2(x)$ measured by the same experiment (NA4) multiplied by 9/5. The dashed curve shows the effect due to higher-order weak and electromagnetic processes for which the data are corrected.





GeV the spectrum is even flatter than in this extreme model, indicating a 'nuclear enhancement' effect.

The Ames Lab. – Bologna – CERN – Dortmund – Heidelberg – LBL – Lund – Warsaw Collaboration (R418) are analyzing the longitudinal momentum distribution of leading protons in αα and dd collisions, as well as the correlation between the yields of spectator protons and the nature of high p_T particles.

The R807 Collaboration have measured the αα elastic scattering cross section (Fig. 13). A clear minimum is seen due to the interference between single and double scattering amplitudes.

SPS Programme

Muon beam experiments

The Bologna – CERN – Dubna – Munich – Saclay Collaboration (NA4) have analyzed their earlier measurements of the μ^+–μ^- cross section asymmetry in deep inelastic muon-carbon scattering in terms of a new structure function $xG_3(x)$ ($x \equiv$ Bjorken scaling variable). This 'interference structure function' is sensitive to both the electromagnetic and the weak charges of the quarks. The standard model and the quark parton model predict for the valence quark regime ($x > 0.2$) and for an isoscalar target a constant ratio $xG_3(x)/F_2(x) = 9/5$, where F_2 is the conventional electromagnetic structure function of the nucleon. The experimental result is in good agreement with this prediction (Fig. 14). In addition, the EMC effect has been studied for iron and nitrogen nuclei at high Q^2. Preliminary results are in good agreement with the EMC results and with recent SLAC data at small Q^2.

The European Muon Collaboration (EMC), Aachen – Annecy – CERN – Freiburg – Hamburg – Heidelberg – Kiel – Lancaster – Liverpool – Marseilles – Mons – Oxford – Rutherford – Sheffield – Turin – Uppsala – Warsaw – Wuppertal – Yale, have continued the study of nuclear effects in muon collisions. The yields of secondary particles from carbon and copper targets are found to be remarkably similar to those from free protons; this result is consistent with a quark fragmentation length larger than the nuclear radii and a low quark–nucleon scattering cross section. The study of J/ψ production from iron and hydrogen targets shows instead that the single nucleon cross section in iron is larger than in hydrogen (Fig. 15). This may indicate that the soft gluon density

Figure 15 — World data on the energy variation of the cross-section per single nucleon for inclusive production of J/ψ on Fe and on H_2 and D_2 targets (EMC).

Figure 16 — Values of neutral coupling constants of the electron g^e_V and g^e_A obtained from the CHARM Collaboration. The limits from the measurements of the forward-backward asymmetry in the reaction $e^+e^- \to \ell^+\ell^-$ at PETRA and PEP and of $\bar{\nu}_\mu e$ scattering cross sections select a unique solution.

per nucleon in iron is larger than that in hydrogen since the J/ψ yield is thought to be proportional to the gluon density in the target. In addition, new results have been obtained on the production of forward protons and antiprotons in muon–nucleon scattering and several studies of quark and diquark fragmentation have been made.

Neutrino experiments

The CHARM Collaboration, CERN - Hamburg - Amsterdam - Rome - Moscow (WA18), have made a new measurement of the cross sections for ν_μ and $\bar{\nu}_\mu$ scattering on electrons. The final value of $\sin^2\theta_W$ obtained in these purely leptonic processes is $\sin^2\theta_W = 0.215 \pm 0.032$ (stat) $\pm$ 0.012 (syst). The values obtained for the neutral current couplings g^e_A and g^e_V are shown in Fig. 16 together with limits obtained from other experiments which select the unique solution

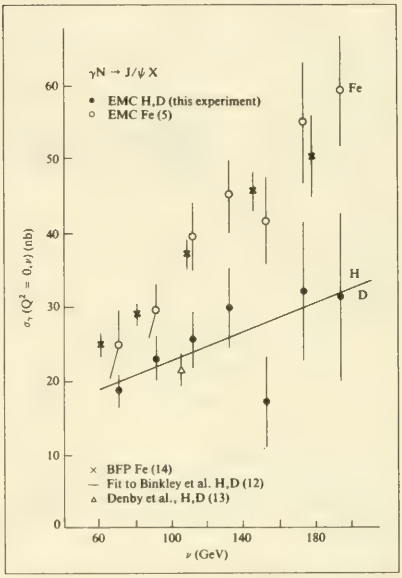
$$g^e_A = -0.54 \pm 0.05\,(\text{stat}) \pm 0.06\,(\text{syst}),$$

$$g^e_V = -0.08 \pm 0.07\,(\text{stat}) \pm 0.03\,(\text{syst}).$$

A value $g^e_A = -1/2$ is predicted by the standard model, in agreement with the experiment. The CHARM II Collaboration, Brussels IIHE - CERN - Hamburg - Moscow - Naples - Rome, are preparing a new detector to repeat these measurements with higher precision.

The CHARM Collaboration have also studied the nucleon longitudinal structure function F_L in charged current ν and $\bar{\nu}$ interactions. The results show a clear deviation from the Callan–Gross relation, interpreted as being due to the finite transverse momenta of partons in the nucleon.

The CDHS Collaboration, CERN - Dortmund - Heidelberg - Saclay - Warsaw, are analyzing the high statistics exposures of the WA1 apparatus to ν_μ and $\bar{\nu}_\mu$ narrowband and wideband beams which resulted in $\sim 10^6$ recorded neutrino interactions. The WA1/2 Experiment took data during 1984 in a high-flux version of the narrowband beam. The data are being analyzed and the measurement of the neutral to charged current ratio should give a value of $\sin^2\theta_W$ with an experimental precision of ± 0.005, similar to the precision aimed at by the CHARM II Collaboration. This precision, in conjunction with the value of $\sin^2\theta_W$ obtained from the Z^0 mass, should give a meaningful test of the higher-order electroweak radiative correction.



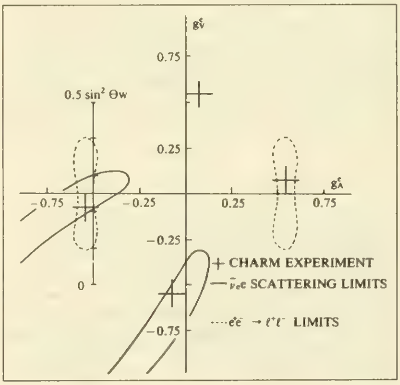
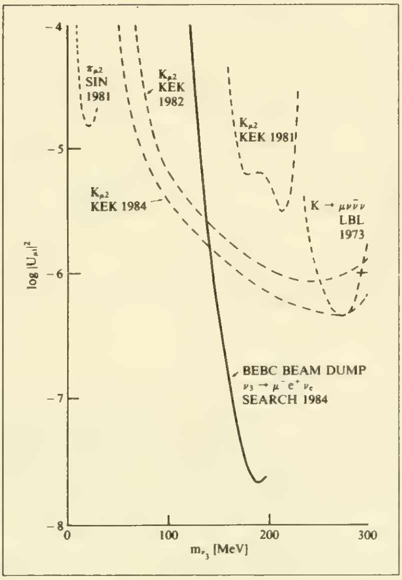


Figure 17—Limits on the mixing matrix elements $|U_{\mu i}|^2$ as a function of the neutrino mass m_{ν_3} derived from the WA66 experiment (full line) and from $\pi \to \mu\nu$ and $K \to \mu\nu$ decays (dashed lines).



Beam dump experiments

The analysis of data from the 1982 CERN experiments, to investigate the properties of neutrinos produced by 400 GeV protons hitting massive copper beam dumps, continues. The CDHS Collaboration (WA68) give a ratio of prompt ν_e to prompt ν_μ of 0.88 ± 0.17, which is consistent with ν_e and ν_μ production being equal as expected if they come from semileptonic decays of charmed particles produced in the dump.

The Aachen – Athens – Bonn – CERN – London (IC) – Munich (MPI) – Oxford – Saclay – Stockholm Collaboration (WA66) are refining the analysis of their beam dump experiment which used BEBC as a neutrino detector. Prompt muon and electron event rates are compatible with being equal. A small ratio (0.21 ± 0.06) of e^+ to e^- event rates is observed indicating a difference between the ν_e and $\bar{\nu}_e$ fluxes; this asymmetry is interpreted as a consequence of the fact that charmed baryons, giving ν_e, have a larger momentum than the associated charmed meson giving $\bar{\nu}_e$.

The same Collaboration have made a search for the decay of heavy neutrinos into $\mu^- e^+ \nu_e$. From the absence of low mass two-prong events indicating such decay, limits have been obtained on their mixing with muon-neutrinos (Fig. 17).

The other BEBC Experiments WA21, Birmingham – Bonn – CERN – London (IC + UC) – Munich (MPI) – Oxford Collaboration, WA25, Amsterdam – Bergen – Bologna – Padua – Pisa – Saclay – Turin Collaboration and WA59, Athens – Bari – Birmingham – Brussels – CERN – London (IC + UC) – Munich (MPI) – Oxford – Palaiseau – Rutherford – Saclay Collaboration, are continuing the data analysis to study structure functions and neutral current processes.

Search for fractionally charged particles

The CHARM Collaboration have performed a new search for charge 1/3 and 2/3 particles produced in proton-nucleus and neutrino-nucleus collisions. They give limits of a few times 10^{-5} per neutrino interactions and 10^{-40} cm^2 for proton-nucleus interactions.

The Bologna (Univ. + INFN) – CERN – Frascati – Rome Collaboration (WA44) are analyzing data from a search for quarks produced in high-energy neutrino interactions. The search is based on the measurement of the track ionization in an avalanche chamber. Extensive studies are being made of all sources of systematic effects which could simulate low ionizing tracks in their apparatus.

Prompt photon and muon pair production

Single photons with large transverse momenta are expected to be produced mainly via QCD Compton (quark + gluon → quark + photon) and annihilation (quark + antiquark → gluon + photon) processes. In particular, the cross section difference

$$\sigma(\pi^- N \to \gamma + X) - \sigma(\pi^+ N \to \gamma + X)$$

is determined by the contribution of the annihilation graph only. Preliminary results obtained by the Bari – Freiburg – Moscow (ITEP) – Munich (MPI) Collaboration (NA24) from 300 GeV/c $\pi^- p$, $\pi^+ p$, and pp interactions (Fig. 18) seem to indicate some discrepancy with the QCD predictions.

Another prompt photon experiment is being carried out by the Geneva – Glasgow – Liverpool – Milan – Neuchâtel Collaboration (WA70) using a fine-grained sampling photon calorimeter covering a large solid angle and the Ω' magnetic spectrometer. The calorimeter is based on a new technique using liquid scintillators contained in teflon tubes, which behave as optical fibers. The data acquisition has started and the analysis is in progress.

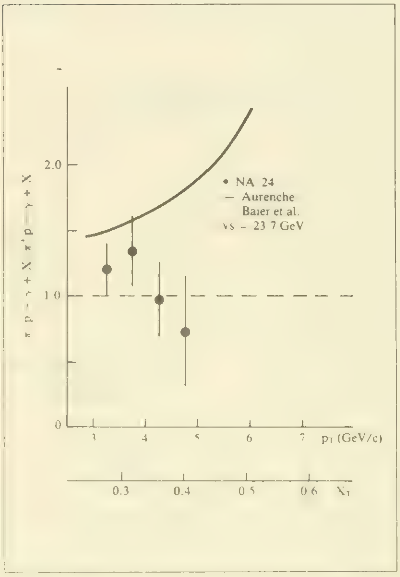
The Athens – CERN – London (IC) – Orsay (LAL) – Palaiseau (EP) – Paris (CdF) – Saclay (CEN DPhPE + DPhN) – Southampton – Strasbourg – Warsaw Collaboration (NA14) are studying high p_T photon production using an incident photon beam. The data processing is nearly completed. A clear excess of prompt photons is observed at transverse momenta > 2.5 GeV/c which is interpreted in terms of QED quark-photon scattering with appropriate QCD corrections.

Direct production of soft photons in hadronic processes is instead expected to be due to QED bremsstrahlung processes associated to the production of charged hadrons. The CERN – Brussels – Mons – Nijmegen – Serpukhov Collaboration (WA27) investigated the production of soft gamma production in K^+p interactions at 70 GeV/c in BEBC. An excess of gammas is found at low p_T (< 60 MeV/c) which is not accounted for by radiative decay of hadrons neither by the expected QED bremsstrahlung and may indicate the existence of other, as yet unknown, sources of soft photons.

Muon pair production by incident hadrons is an important testing ground of QCD. The CERN – Orsay (LAL) – Palaiseau (EP) – Paris (CdF) – Pisa – Saclay Collaboration (NA3) have presented an analysis of 30000 high mass dimuons ($M_{\mu\mu}$ > 4.5 GeV/c^2). They determine the K factor (σ experimental/σ predicted in the leading log approximation) for different values of the Feynman-x and of the mass of the pair.

The CERN – Naples – Palaiseau (EP) – Strasbourg – Zurich (ETH) Collaboration (NA10) have presented results from their 194 GeV/c π^- run. A study of the Drell-Yan continuum indicates an unexpected scaling violation for muon pair masses above the Υ. Data taking is continuing in order to understand the nature of this violation. In addition evidence has been obtained that QCD higher twist effects are needed to describe the angular distribution of the $\mu^+\mu^-$ continuum. Finally, a study of a sample of 2000 Υ events shows that their x_F and p_T distributions are similar to those of Drell-Yan pairs.

Figure 18 — The (NA24) preliminary results on the ($\pi^-p \to \gamma + X$)/($\pi^+p \to \gamma + X$) ratio as calculated from the measured γ/π^0 cross-sections ratio in π^-p and π^+p collisions. For comparison a QCD prediction is shown.



Heavy flavours

An extensive program is being carried on to study the production and decay of hadrons carrying charm and beauty.

The Aachen – Brussels – Bombay – CERN – Duke – Genoa – Japan – Liverpool – Madrid – Mons – Oxford – Padua – Paris (CdF + Paris VI) – Rome – Rutgers – Rutherford – Serpukhov – Stockholm – Strasbourg – Tennessee – Turin – Trieste – Vienna – Zeuthen Collaboration (NA27) using the LEBC-EHS set-up have completed the data acquisition phase of their experiment. Final results have been obtained on the D^0 and D^+ lifetime, branching ratios and cross sections. The lifetime values are

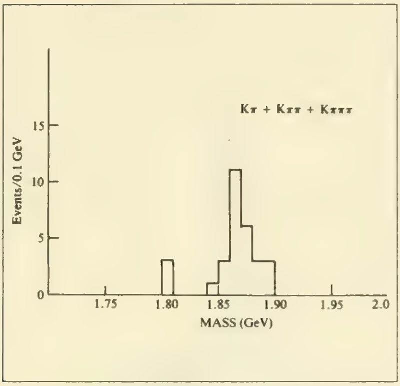
$$\tau_{D^0} = 3.5^{+0.9}_{-0.7} \times 10^{-13}\,\mathrm{s},$$

$$\tau_{D^+} = 10.1^{+5.0}_{-2.8} \times 10^{-13}\,\mathrm{s}$$

and confirm the previous findings that D^0 and D^+ do

Figure 19—D^0 and D^* decays from the NA32 experiment (~ 10% of π^- data).

Figure 20—First observation by WA62 of the charmed strange baryon A^+ decaying into $\Lambda K^- \pi^+\pi^+$.



not have the same lifetime. Results have also been obtained on charm-charm correlations, allowing a test of various models of hadronic charm production. While the bulk of the data can be interpreted in terms of central production, a clear leading particle effect is observed. This last effect is not fully understood in terms of QCD-based models.

The ACCMOR Collaboration, Amsterdam – Bristol – CERN – Cracow – Munich (MPI) – Rutherford (NA32), are pursuing a systematic study of charm production and decay in hadronic interactions using the ACCMOR spectrometer and a high resolution Si μ-strip vertex detector. In 1984 the physics goal was to collect a high statistics sample of charged and neutral D-mesons, to study their production with different incoming particles (π^-, K^-, p), and to determine their lifetime with a precision of better than 10%. So far a small sample of data has been analyzed yielding 30 fully reconstructed D^0 and $D^\pm$ decays in the decay modes $K^\pm\pi^\pm\pi^\mp\pi^\mp$ (Fig. 19). A previous data sample, obtained by triggering in part on ϕ-mesons and in part on semi-leptonic charm decays, has been analyzed yielding 25 Cabibbo suppressed $D^\pm \to K^+K^- \pi^\pm$ decays and a few $\Lambda_c \to pK\pi$ candidates.

The Bristol – Geneva – Heidelberg – Lausanne – London (QMC) – Rutherford Collaboration (WA42 and WA62) continue the analysis of data collected in the SPS hyperon beam up to 1982. The lifetime of the charmed strange hyperon A^+ observed for the first time in this experiment (Fig. 20) has been determined to be

$$\tau_{A^+} = 4.8^{+2.9}_{-1.8} \times 10^{-13}\text{s}.$$

The same collaboration have obtained first evidence for the T^0 baryon in the decay to $\Xi^- K^- \pi^+\pi^+$ with a mass of (2740 ± 25) MeV/c^2.

The NA14 Collaboration are preparing and testing an experiment to study the photoproduction of

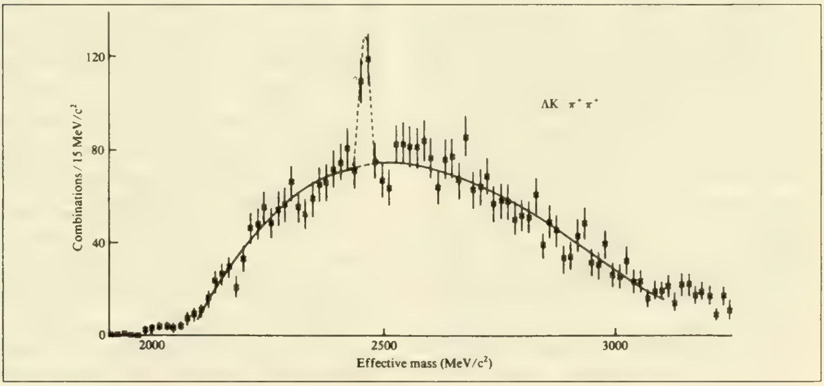
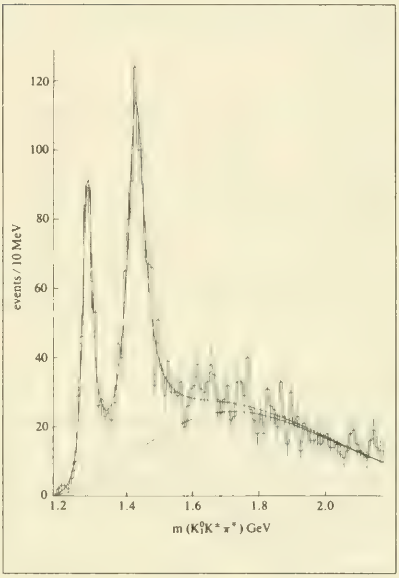


Figure 21—$K^0K^{\pm}\pi^{\mp}$ mass spectrum from the reaction $(\pi^+/p)p \rightarrow (\pi^+/p)\,X^0p$; $X^0 \rightarrow K^0K^{\pm}\pi^{\mp}$ at 85 GeV/c (WA76). Clear peaks are present at mass values corresponding to the D(1285) and the E(1420).



heavy flavours using the NA14 spectrometer and a Si μ-strip vertex detector.

The Bonn – CERN – Lancaster – Manchester – Rutherford- Sheffield Collaboration (WA69) are studying the photoproduction of high mass states fragmenting into multiparticle final states. They use the Ω' spectrometer, its downstream electromagnetic calorimeter (built by WA70) and a Ring Imaging CHerenkov (RICH) detector built by the British part of the collaboration. The data taking and the analysis have started.

Two collaborations have taken data to study hadroproduction of beauty in nuclear emulsion. The CERN – Genoa – Milan – Moscow – Paris – Rome – Santander – Valencia Collaboration (WA71) use the Ω' spectrometer, its downstream RICH detector and electromagnetic calorimeter. The Bari – Brussels – CERN – Dublin – Japan – London (UC) – Rome – Turin Collaboration (WA75), use a downstream muon detector. Both experiments incorporate a Si μ-strip vertex detector.

Another Collaboration, Bari – Brussels – CERN – London (UC) – Rome – Turin (WA78), have started a search for pairs of particles carrying beauty by dumping a π^- beam on a target calorimeter and detecting the muon signals coming from the $b\bar{b}$ semileptonic decay chain.

Other SPS Experiments

The Athens – Bari – Birmingham – CERN Collaboration (WA76) are studying the mesons produced in the central rapidity region in exclusive reactions where, to date, little data exists. One aim of the experiment is to look for the so-called glueball meson states. The experiment was performed in the Ω' spectrometer, the beam being composed of π^- and protons of 85 GeV/c. The channel $(\pi^+/p)p \rightarrow (\pi^+/p)X^0p$, $X^0 \rightarrow K^0_1K^{\pm}\pi^{\mp}$ has been analyzed in detail. The $K^0_1K^{\pm}\pi^{\mp}$ mass spectrum (Fig. 21) shows two peaks at mass values corresponding to the D and E/iota mesons. Analysis of the spin-parity of the states showed that both have $J^P = 1^+$. Thus, if the $J^P = 0^-$ value found for the iota-meson at SLAC in the reaction $\psi \rightarrow \gamma$iota is confirmed, it appears there exist two mesons with the same decay mode and similar masses but different spin parities.

Both D and E states have also been observed (Fig. 22) in the reaction $\pi^-p \rightarrow M^0n$, $M^0 \rightarrow \eta\pi^0\pi^0 \rightarrow 6\,\gamma$ at 100 GeV/c by the Annecy – Belgium – Los Alamos – Serpukhov Collaboration (NA12). This experiment makes use of a 4000 cell Cerenkov hodoscope (GAMS), which allows the measurement of the momentum vector of each gamma in a multi-gamma event. The spin parity assignment $J^P = 1^+$ seems favoured for the peak in the E/iota region.

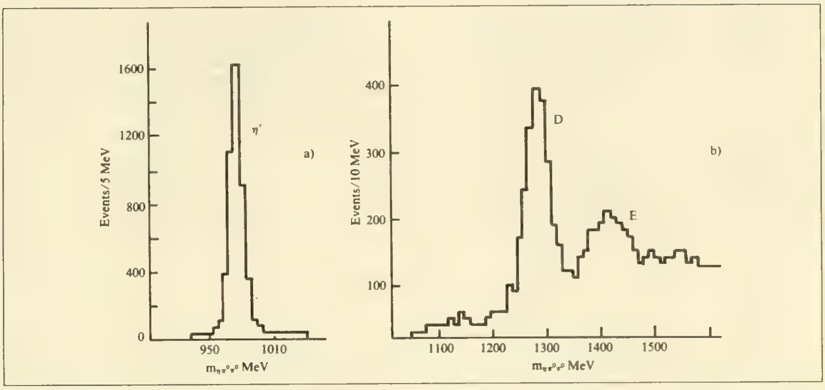
The Athens – Bari – Birmingham – CERN – Paris (Uni VI + CdF) Collaboration (WA77), using the Ω' Spectrometer, have started a search for high p_T direct production of resonances amongst which direct production of gluonium states can be expected.

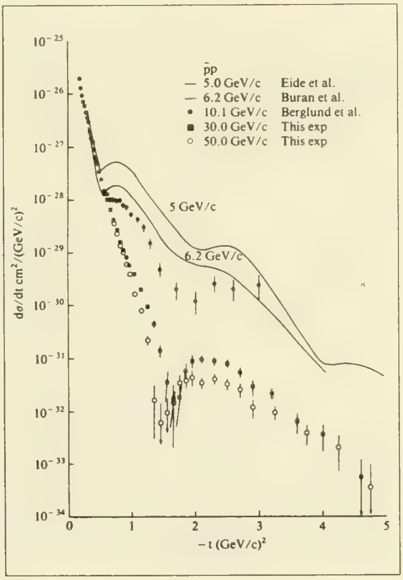
Another Ω' Experiment (WA74), by the CERN – Lisbon – Neuchâtel – Paris VI Collaboration, has studied the forward inclusive production of Λ^0's in K^-p interactions at 12 and 16 GeV/c. In the forward direction, the Λ^0 polarization is found to be large and to have a strong p_T dependence.

The Annecy – CERN – Copenhagen (NBI) – Genoa – London (UC) – Oslo Collaboration (WA7), using a two-arm spectrometer, have measured elastic

Figure 22—$\eta\pi^0\pi^0 \rightarrow 6\gamma$ mass spectrum from the reaction $\pi^- p \rightarrow M^0 n$, $M^0 \rightarrow \eta\pi^0\pi^0$ at 100 GeV/c (NA12). Clear signals are present at mass values corresponding to the η' (a) and to the D(1285) and E(1420) (b).

Figure 23—Antiproton-proton differential cross section at 30 and 50 GeV/c (WA7), compared with data at lower energies.





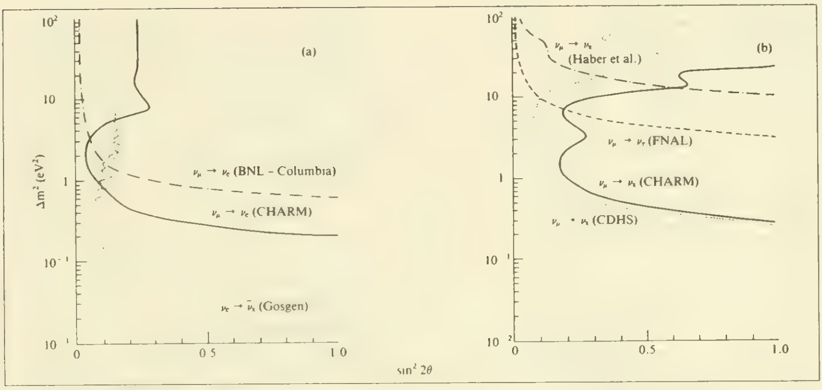
differential cross sections of $\pi^{\pm}p$, $K^{\pm}p$, $p\bar{p}$ and pp scattering at incident momenta of 20, 30 and 50 GeV/c in the momentum transfer range $0.5 < |t| < 8$ GeV^2. An unexpected dip-bump structure is observed in the $p\bar{p}$ elastic differential cross-section at 30 and 50 GeV (Fig. 23). The dip and its observed displacement with energy provide a challenge to theoretical models.

The CERN - Frascati - London (Westf. Coll.) - Milan - Pisa - Southampton - Turin - Trieste Collaboration (NA7) are completing the analysis of the data taken at the FRAMM spectrometer, to study the electromagnetic form factor of the pion. The data in the space-like region are fitted by a pole form with a pion radius $\langle r^2\rangle^{1/2} = 0.657 \pm 0.012$ fm. The analysis of data on the kaon form factor has started.

Another Collaboration using the FRAMM spectrometer, [Clermont-Ferrand - Frascati - Milan - Pisa - Turin - Trieste - London (Westf. Coll.)] (NA29), are at present completing the analysis of $\pi^-\pi^0$ production via Primakoff effect on nuclei.

Two collaborations using the European Hybrid Spectrometer (EHS), namely the Aachen - Berlin - Brussels - Cracow - Erevan - Helsinki - Nijmegen - Rio de Janeiro - Serpukhov - Warsaw Collaboration (NA22), and the Bombay - CERN - Genoa - Innsbruck - Japan - Madrid - Mons - Rutgers - Serpukhov - Tennessee - Vienna Collaboration (NA33), are analyzing their data to study low p_T hadronic collisions.

Figure 24 — The 90% confidence limits on neutrino oscillations obtained by experiment PS181 together with those from other experiments:
(a) from the appearance $\nu_\mu \to \nu_e$ experiment;
(b) from the $\nu_\mu \to \nu_x$ experiment.
The regions to the right of the curves are excluded.



The Ames Lab. – CERN – Chicago – Lund – Paris (Univ. VI) Collaboration (NA30) have completed their precision measurement of the π^0 lifetime using an arrangement where the decay gammas are converted in a thin foil at variable distance from a thin target in which π^0's are produced. Preliminary results give a π^0 lifetime $\tau = (0.892 \pm 0.02) \times 10^{-16}$ s. The previous average obtained using the Primakoff effect is $\tau = (0.83 \pm 0.06) \times 10^{-16}$ s.

The Annecy (LAPP) – Lyon (IPN) – New-York (Albany Univ.) Collaboration (NA33) are measuring the e^+e^- pair production cross-section by high energy photons incident along the major axial direction of a germanium crystal. The aim is to look for the recently predicted 'crystal-assisted pair creation' which should largely exceed the Bethe-Heitler process rate for photon energies of a few tens of GeV. An enhancement of the cross-section was found, but about three times smaller than foreseen by the theory. The experiment will continue in 1985.

PS Programme

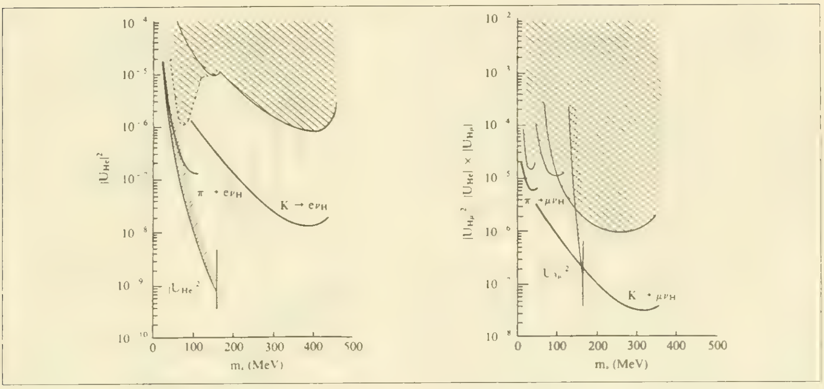
Neutrino Physics

The CHARM Collaboration (CERN–Hamburg–Amsterdam – Rome – Moscow, PS181) have now published their final results on neutrino oscillations. The experiment used two neutrino detectors placed at 123 m and 903 m from the neutrino source known to provide essentially muon neutrinos (ν_μ). They looked simultaneously for the appearance of electron neutrinos (ν_e) and the disappearance of ν_μ's. An upper limit of 2.7% (90% C.L.) was obtained for the fraction of ν_μ's transformed into ν_e's. For complete mixing ($\sin^2 2\theta = 1$) this gives a limit $\Delta m^2 \leq 0.20$ eV^2 and a minimum value of the mixing parameter $\sin^2 2\theta = 0.04$ at $\Delta m^2 = 2$ eV^2. Oscillations $\nu_\mu \to \nu_x$, where ν_x may be ν_τ or a heavier neutrino, were also looked for by measuring the disappearance of ν_μ's between the two detectors. Assuming complete mixing, the limit $\Delta m^2 \leq 0.29$ eV^2 has been obtained at the 90% confidence level. It is worthwhile recalling the results already reported last year by the CDHS Collaboration (CERN – Dortmund – Heidelberg – Saclay – Warsaw – Washington Collaboration, PS169) which looked for ν_μ oscillations by comparing the rates of ν_μ charged-current interactions in two detectors located at 130 m and 885 m from the target. At the 90% C.L. Δm^2 values between 0.26 and 90 eV^2 were excluded for $\sin^2 2\theta = 1$ while fixing a minimum value of $\sin^2 2\theta = 0.053$ at $\Delta m^2 = 2.5$ eV^2.

The complete information derived from the two experiments is summarized in Fig. 24 together with results obtained in other laboratories.

The Collaboration of Annecy – Athens – CERN – Paris – Rome (PS191) searched for the decay of heavy neutrinos into $e^+e^-\nu_e$. The detector, which was

Figure 25 — Limits (90% CL) obtained by the neutrino decay experiment PS191 on the mixing parameters — elements of the Kobayashi–Maskawa matrix — as a function of the mass of hypothetical neutrinos.



assembled and tested just before the run in the first half of 1984, is a simple one. It consists of a decay volume 12 m long and 6×3 m^2 surface filled with helium in which seven equally spaced planes of flash tubes define the tracks of charged particles. It is followed by an electromagnetic calorimeter — 7 radiation lengths equivalent — composed of 20 planes of flash tubes between each of which 6 mm thick Fe plates were inserted. A scintillator hodoscope, placed inside the calorimeter after the first two radiation lengths, was used as trigger.

It is estimated that about 10^{16} ν's passed through the detector. No decay was observed and it can be estimated, see Fig. 25, that, for example, the coupling strength measuring the overlap between a heavy neutrino mass between 100 and 400 MeV and a ν_μ or ν_e neutrino is smaller than 10^{-6} and 10^{-8}, respectively.

LEAR Experiments

The very successful operation of LEAR and the extensive physics runs made in 1984 at different $\bar{p}$ energies have allowed many of the experiments started in 1983 to accumulate statistics that, although generally still far from those estimated necessary to accomplish their goals, allow them to study in detail the performance of their equipment and analysis programmes. In so doing, preliminary results on the more prominent phenomena occurring have been obtained. They are summarized in the following paragraphs.

X-rays

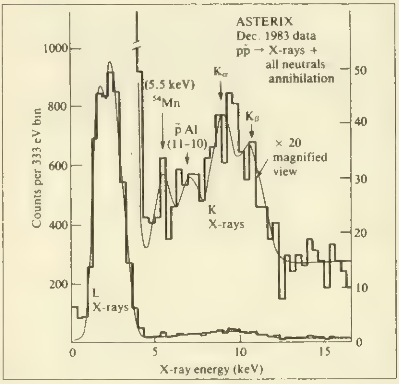
X-rays are emitted in radiative transitions to the lowest states of antiprotonic atoms preceding $\bar{p}$N annihilation at rest. Their yields and energies provide important information about the atomic cascade process and the strong $\bar{p}$N interaction at threshold which broadens and shifts the levels with respect to their Q.E.D. values. The studies require gaseous targets since the antiprotonic atoms formed in liquid targets annihilate — due to collisional Stark mixing — from high nS states without X-ray emission. The very high $\bar{p}$ fluxes now available at LEAR compensate the poor stopping power of gas targets.

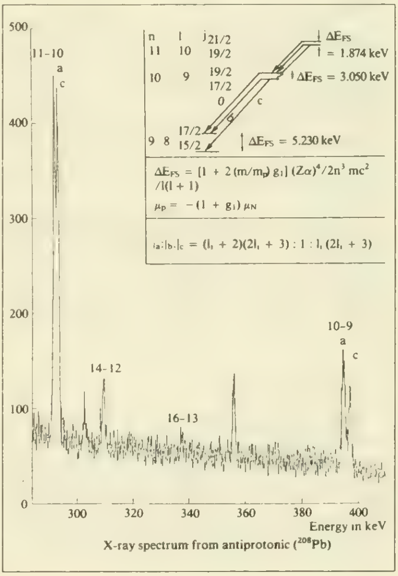
Two experiments have thus observed for the first time X-ray transitions to the 1s ground state of the $\bar{p}$p atom.

One, CERN - Mainz - Munich - Orsay (LAL) - Vancouver - Victoria - Zurich Collaboration (PS171), stop antiprotons in a hydrogen target located inside a large magnetic spectrometer. The target is surrounded by a cylindrical projection chamber measuring the energy (precision 1100 eV F.W.H.M. at 5.5 keV) and the conversion point of the X-rays as well as the tracks of charged annihilation products. The X-ray energy spectrum, shown in Fig. 26, has been obtained in a 6

Figure 26 — The X-ray energy spectrum observed by experiment PS171 from antiproton-proton atoms which subsequently annihilated at rest into neutral particles only. Weak but significant production of K-lines is observed.

Figure 27 — The X-ray energy spectrum from antiprotonic ^{208}Pb observed by experiment PS176. The fine structure of the lines from transitions from the level with principal quantum number n = 10 to n = 9 and from n = 11 to n = 10 is clearly seen.





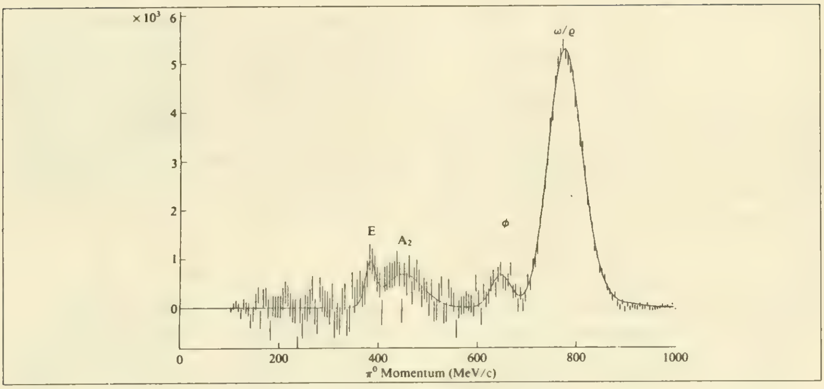
hour run requiring only neutral annihilation products to suppress background from inner bremsstrahlung. L-series X-rays are contained in the large peak between 1.4 and 3.6 keV, while the K-series appears as a broad structure between 8 and 11 keV. The relative yield of K to L X-rays is $(2 \pm 1)\cdot 10^{-2}$ due to the large annihilation width of the 2p level. A fit based on two gaussian contributions from K_α and K_β lines with fixed Q.E.D. separation and the experimental resolution gives a repulsive shift of the 1s level $\Delta E(1s) = -0.5 \pm 0.3$ keV. The total L-series yield has been determined to be 0.13 ± 0.02 per stopping $\bar{p}$ from a study of annihilations into charged particles.

The other experiment, a Collaboration of Birmingham - Rutherford Appleton Laboratory - College of William and Mary (U.S.A.) - NIKHEF (Amsterdam), (PS174), stop $\bar{p}$'s in a large aluminium flask containing gas at atmospheric pressure and maintained at temperatures from 30 K to 300 K. The X-rays are detected in a 300 mm^2 × 5 mm SiLi detector. Although still limited by statistics, they also observe K-series transitions and give preliminary values for the shift and width of the 1s state: $\Delta E_{1s} = -0.75 \pm 0.19$ keV and $\Gamma_{1s} = 1.14 \pm 0.24$ keV, respectively. $\bar{p}^4$He spectra were used to test and calibrate the apparatus. As a by-product strong interaction effects were measured with the following results: $\Delta E_{(2p)} = -7.4 \pm 3.5$ eV, $\Gamma_{(2p)} = 35 \pm 15$ eV and $\Gamma_{(3d)} = 2.4 \pm 0.5$ meV.

X-ray spectra of antiprotonic atoms and γ-rays spectra from residual nuclei after $\bar{p}$ absorption are being studied by the Basel - Karlsruhe - Strasbourg - Thessalonica Collaboration (PS176). The spectra of oxygen isotopes have been studied to disentangle the $\bar{p}$ n from the $\bar{p}$p interactions. The cascade is observed to stop at the principal quantum number n = 3, where the strong interaction effects should be observed. By comparing the displacement and width of the line from the n = 4 to the n = 3 level observed in ^{17}O and ^{18}O relative to those observed in ^{16}O, the zero energy $\bar{p}$ n scattering length can be determined under simple but reasonable assumptions. The ϱ-parameter (ratio of the real to the imaginary part of the forward scattering amplitude) deduced from it is found to be $\varrho = -0.73 \pm 0.13$, a value which present theoretical models would indicate to correspond to the existence of a bound state close to threshold.

$\bar{p}\,^{208}$Pb X-rays have also been studied by the same Collaboration, Fig. 27. The fine structure splitting of the lines from n = 10 to n = 9 and from n = 11 to n = 10 have been measured: 2.2 keV and 1.2 keV,

Figure 28 – The background subtracted inclusive momentum spectrum of π^0's observed by experiment PS182 in antiproton-proton annihilations at rest. Besides strong production of the channel $\bar{p}p \rightarrow \pi^0(\omega/\varrho)$ indications for $\bar{p}p \rightarrow \pi^0\phi$, π^0A_2 and π^0E are observed.



respectively. From these values a determination of the $\bar{p}$ magnetic moment is being calculated.

Search for Narrow Resonances

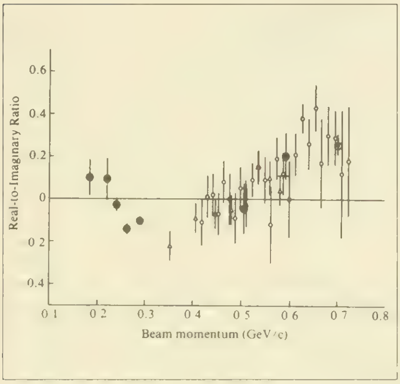
Potential models of the $N\bar{N}$ interaction and, more generally, Q.C.D.-inspired models predict the existence of resonances other than the classical ($q\bar{q}$) ones. Different experiments at LEAR are searching for them. The results obtained so far come from studies of inclusive reactions where, if produced in quasi two-body reactions, the resonances would manifest themselves through the appearance of lines in the momentum spectrum of the recoiling pions (charged or neutral), γ-rays or a narrow resonance like the η or η'. Narrow resonances would give nearly monochromatic lines and their observation in inclusive spectra should be favoured.

The Athens – U.C. Irvine – New Mexico – Pennsylvania State – Temple Collaboration (PS183) have stopped $\sim 10^{10}$ antiprotons in a liquid hydrogen target and measured the momentum spectrum of charged particles entering a magnetic spectrometer placed on one side of the target. At the 3σ level no evidence was found for narrow states with frequencies greater than 6×10^{-4} per $\bar{p}p$ annihilation.

The CERN – Mainz – Munich – Orsay (LAL) – Vancouver – Victoria – Zurich Collaboration (PS171), using a spectrometer covering a solid angle of $\sim 0.6 \times 4\pi$ around a hydrogen gas target, have examined the spectrum of $\sim 7 \times 10^5$ charged pions coming from events fully reconstructed in the target. At the 5σ level they set an upper limit of 2×10^{-3} per annihilation for the production of narrow states in the mass range 1100 to 1670 MeV. Contrary to other experiments, the large solid angle covered by the spectrometer of this Collaboration allows the study of many completely determined annihilation channels. Analyses now in progress are extending the search for resonances to multibody final states. Detection of $K^0_S \rightarrow \pi^+\pi^-$ decays in $\bar{p}p \rightarrow K^0_SK^0_S$ and $K^0_SK^0_L$ annihilations and, through the use of dE/dx information provided by the X-ray detector, of reactions like $\bar{p}p \rightarrow K^+K^-\pi^+\pi^-$ have been reported. Channels containing $K\bar{K}$ pairs as well as pions are thus becoming available for investigation.

PS182 (Basel – Stockholm – Thessalonica Collaboration) is designed to measure the energy of γ's, π^0's and η's produced in $\bar{p}p$ annihilations at rest in liquid hydrogen. The apparatus consists of one lead-glass matrix covering an azimuthal angle of 150° and two small BGO systems that can be rotated around the target relative to each other and to the lead-glass wall. The analysis of the single γ-energy is still in progress. The reconstructed π^0 momentum spectrum shows, Fig. 28, a strong contribution of the channel $\bar{p}p \rightarrow \pi^0 + (\varrho$ and $\omega)$ and indications for the existence of annihilation channels: $\bar{p}p \rightarrow \pi^0\phi$, π^0A_2 and π^0E. The η momentum spectrum shows strong production of the

Figure 29 — Values of the ϱ parameter (ratio of the real to the imaginary part of the forward antiproton-proton scattering amplitude) measured by Experiment PS173 (black dots) together with those obtained in other experiments.



channel $\bar{p}p \rightarrow \eta$ + (ϱ and ω) with a strength (~ 3% per annihilation) which, surprisingly, is about the same as that of the equivalent π^0 channel.

Cross-section Measurements

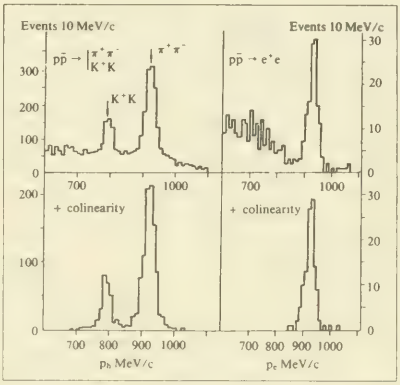
Experiment PS173 [Max-Planck (Heidelberg) - University of Heidelberg Collaboration] are measuring differential $\bar{p}p$ cross-sections in the momentum range from 150 MeV/c to 600 MeV/c.

The elastic differential cross-section measurement covers also the Coulomb-nuclear interference region and thus allows the determination of ϱ — the ratio of the real to the imaginary part of the forward scattering amplitude. The total cross-section is obtained via the optical theorem.

Data have been obtained using $\bar{p}$ with incident momenta of 600, 300 and 200 MeV/c and at intermediate momenta by using a carbon degrader. Above 400 MeV/c the measured cross-sections agree with previous measurements. In the region below 300 MeV/c, where these are the first available results, the annihilation and total cross-sections increase faster than predicted by any model of the $\bar{p}p$ interaction. The values of ϱ show an unexpected increase below 240 MeV/c (Fig. 29), which may be a hint of resonance production close to the $\bar{p}p$ threshold.

Experiment PS172 (Amsterdam (NIKHEF) - Geneva - London (QMC) - Surrey University - Trieste Collaboration) have published the results of a measurement made last year of the $\bar{p}p$ total cross-section from 388 to 599 MeV/c in momentum steps of from 5 to 10 MeV/c. The measurements were made in a conventional good geometry transmission experiment. Statistical errors are typically ±0.4% and the normalization uncertainty is ±0.7%. One of the motives for studying this region is that previous experiments have given contradictory results about the existence of a resonance, called the S(1936) meson, appearing at a momentum of about 500 MeV/c. With a mass resolution of about 1.4 MeV/c^2 this Collaboration find — at the 90% C.L. — an upper limit of 2 mb MeV/c^2 for the strength of a resonance of width $\Gamma \leq$ 3.5 MeV/c^2. This is in contrast to values as high as 24 mb MeV/c^2 reported by some experiment giving positive evidence.

Figure 30 — Momentum distributions obtained with a trigger requiring two hadrons (left) or two electrons (right) in the detector of Experiment PS170. The top histograms show the raw data while for those at the bottom a collinearity cut has been applied.



Electromagnetic Form Factor of the Proton in the Time-Like Region

Experiment PS170 (Ferrara - Padua - Saclay - Turin Collaboration) have taken data on the reaction $\bar{p}p \rightarrow e^+e^-$ for $\bar{p}$ momenta from 0 to 300 MeV/c and at 600 MeV/c. The expected cross-section is very small, 10^{-6}–10^{-8} of the total, and a rejection of the order of 10^{10} against hadrons and other background sources is required. Fig. 30 shows the good separation obtained to isolate $\bar{p}p \rightarrow e^+e^-$ and $\bar{p}p \rightarrow \pi^+\pi^-$, K^+K^- annihila-

tions at rest, where so far, 300 e^+e^- events have been obtained. The resulting branching fraction is: $\bar{p}p \rightarrow e^+e^-/\bar{p}p \rightarrow$ total $= (4.8 \pm 0.7) \cdot 10^{-7}$ giving for the form factor a value of 0.62 ± 0.06, assuming $|G_E| = |G_M|$. Analysis at 600 MeV/c is in progress and 30 e^+e^- events have already been selected.

$\bar{p}p \rightarrow \Lambda\bar{\Lambda}$ Annihilation

The PS185 Experiment (Carnegie-Mellon – CERN – Erlangen-Nuremberg – Freiburg – Los Alamos – Saclay – Uppsala – Vienna Collaboration) studying this annihilation had its first run in 1984 at incident momenta 1.48 and 1.51 GeV/c, which correspond to energies of 16 and 26 MeV above threshold. Several hundred fully reconstructed events have been obtained at each momentum proving that the apparatus performs as well as expected. The preliminary results show that there are important amplitudes with orbital momentum $\ell > 0$ in the production process.

$\bar{p}$-Nucleus Interactions

The results of PS184 (Grenoble – Saclay – Strasbourg – Tel Aviv Collaboration) on $\bar{p}+{}^{12}C$ elastic scattering at 310 MeV/c were given in last year's Report. They have now been extended at 310 and 600 MeV/c to ^{12}C, ^{40}Ca and ^{208}Pb. An optical model analysis of the data shows the results to be well explained with a strongly absorptive (imaginary) potential together with a weaker real attractive potential.

$\bar{p}p$ reactions on ^{12}C, ^{63}Cu and ^{209}Bi have been studied at 600 MeV/c in a search for nuclear-bound or resonant states formed by antiprotons and nuclei. The suggested mechanism would consist in the incident $\bar{p}$ transferring its momentum to a proton and getting thereby trapped in the nucleus. An enhancement would then appear in the energy spectrum of the knocked-out proton. No evidence for this is found, the gross features of the spectra being explained reasonably well by the intranuclear cascade model.

Experiment PS179 (Dubna – Frascati – Padua – Pavia – Turin Collaboration) have reported preliminary results on $\bar{p}^4He$ and $\bar{p}Ne$ interactions at 200, 300 and 600 MeV/c incident momenta. A self-shunted streamer chamber placed in a magnetic field of 0.8 T is used as detector.

Reaction cross-sections have been determined and found to agree with the general trend observed at higher momenta for different nuclei. Comparison of the results with those obtained elsewhere at equivalent energies shows the reaction cross-section to follow an $A^{2/3}$ law from hydrogen to lead.

The results on the cross-section $\bar{p} + {}^4He \rightarrow {}^3He + X$ at 600 MeV/c appear to be of particular interest. Using the presently observed abundances of ^3He and ^4He these may be used to place an upper limit of $\sim 10^{-3}$ on the ratio of $\bar{p}$ to p in the early stages of our universe.

Channelling Radiation

The studies of channelling radiation by the Aarhus – CERN – Strasbourg Collaboration (PS188) have continued in 1984. A new position-sensitive photon detector (consisting of 100 CdTe solid-state detectors) was used to demonstrate the possibility of obtaining monoenergetic photon beams. The photons are located with an accuracy of 0.8 mm giving an angular resolution of $\pm 40\,\mu$rad.

Positrons are sent into an Si crystal where they oscillate between the crystal planes and emit radiation. The e^+ beam is then deflected in a magnetic field and the radiation detected in the CdTe array through the conversion of the photon into an e^+e^- pair. The energy of the pair is determined by stopping them in a big scintillator. A strong, monoenergetic photon beam is obtained in the forward direction over a relatively small background.

SC Programme

ISOLDE

Over more than four years the collinear fast-beam laser spectroscopy experiments at ISOLDE have yielded a lot of systematic information about nuclear moments, radii and deformations, of which the most recent highlight is the further evidence for shape-asymmetric (octupole-deformed) nuclear ground states in the heavy radium isotopes.

One experiment is now focusing on a particular nucleus which plays a key rôle in the understanding of nuclear magnetic moments. ^{207}Tl is the only known nucleus with a single $s_{1/2}$ particle or hole and a doubly-magic core (^{208}Pb). It thus constitutes a unique test case for theory, because of its relatively simple struc-

Figure 31 — *Photomicrographs showing head-on views of an etched track of a 30 MeV ^{14}C nucleus emitted in a radioactive decay of a ^{223}Ra nucleus. The diameter and depth of a track (dark circular feature) give its charge and energy; lighter background features are due to recoil atoms struck by alpha particles. Branching ratios as low as ~ 10^{-11} for ^{14}C emission relative to α emission have been seen. To appreciate the extraordinary signal to noise ratio of the technique, note that 2 × 10^5 alpha particles struck the area on the left and 5 × 10^6 alpha particles struck that on the right.*

ture, and because the orbital part of the magnetic moment — usually strongly affected by meson exchange currents — is expected to be zero. The remaining deviation from the single particle Schmidt value should be explained by core-polarization effects.

ISOLDE can provide strong beams of ^{207}Tl (half-life = 4.77 m) because of the lucky chance of three successive rapid α-decays from the mother ^{219}Fr which is strongly produced by spallation of thorium. The magnetic moment has been determined by relating the optical hyperfine structure of ^{207}Tl to those of the stable isotopes, ^{203}Tl and ^{205}Tl. The future will show whether a similar experiment can be performed in the 1.3 s isomer ^{207m}Tl. This $h_{11/2}$ state would be a spin-orbit partner to the $h_{9/2}$ ground state of ^{209}Bi, and by a combination of their magnetic moments one could isolate the complementary information about meson exchange contributions to the orbital part.

The intense sources of Fr and Ra nuclei which can be provided by ISOLDE allow a systematic study of the exotic ^{14}C decay-mode, recently discovered in ^{223}Ra by Rose and Jones from Oxford.

In a first exposure of polycarbonate track-recording films, see figure 31, to the ISOLDE sources, two new cases of ^{14}C decay were discovered in ^{222}Ra and ^{224}Ra. The observed branching ratios, as low as 10^{-11} for ^{14}C emission relative to alpha emission, might tell us about the validity of intranucleus clustering concepts and provide us with improved knowledge of internucleus potentials and extremely asymmetric fission phenomena.

Muon Spin Rotation (μSR) Experiments

The μSR techniques developed at the SC have achieved a high degree of sophistication and are providing very interesting results with muons probing not only local or hyperfine fields and, generally, magnetic properties of materials but also giving information

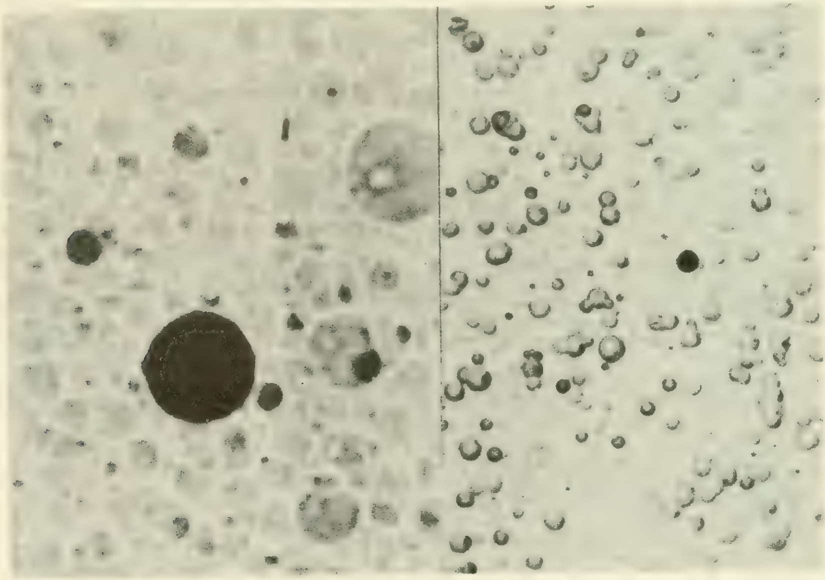
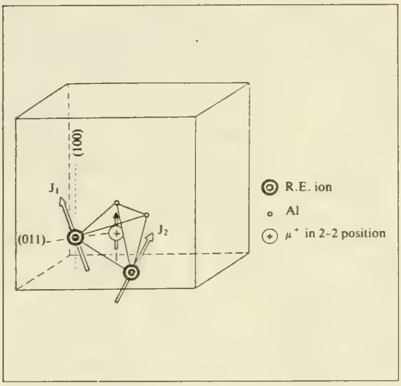


Figure 32—Spin interactions of the μ^+ with paramagnetic compounds of the type $REAl_2$. The μ^+ is here situated in a tetrahedron formed by 2RE and 2 Al atoms (SC65 Experiment).



about the physics and chemistry of different molecules.

Some of the results obtained in 1984 are summarized below.

Experiment SC65 (CERN - Grenoble - Uppsala Collaboration) have measured local spin correlations in the rare earth intermetallics $(RE)Al_2$. In these systems Fig. 32, the μ^+ spin is surrounded by two nearest neighbour RE spins which flip at a rate of 10^{12}–$10^{13}\ s^{-1}$ in the paramagnetic region. This paramagnetic relaxation, as monitored by the μ^+ spin, has been explained quantitatively as a result of a) relaxation of the 4f-spin vs. conduction electrons, b) relaxation through 4f–4f interactions. In the latter process pair correlations between RE spins are observed to persist for temperatures well above T_c.

Muons implanted into hexagonal compounds like Fe_2P have been studied in particular at temperatures close to the first order phase transition. No evidence was found for long-lived spin correlations above T_c and the transverse precession signal disappears in the ferromagnetic state.

Experiments SC68 (Parma University) and SC81 (CERN - Parma - Rutherford Collaboration) have used a new and more efficient spectrometer using proportional wire chambers for a better determination of the coordinates of the incident μ^+ and decay e^+. They have obtained results on the changes of electronic structure of molecular crystals as they are cooled through a phase transition.

The Collaboration CERN - Geneva - Julich - Uppsala (SC76) study the diffusion rate and trapping site for μ^+ in metal hydrides at temperatures in the range 10–300 K.

They have used $Z_rV_2H_x$, with $x = 0, 3.0, 3.5$, and 4.0. The $x = 4$ curve shows a plateau in the range 100–170 K indicating that the μ^+'s are mobile between a limited number of H-sites. Above 170 K, where also the protons become mobile, the muons diffuse over long distances in the sample.

The Collaboration Munich - Uppsala - Grenoble (SC93) study the effects of high pressure at low temperatures on local electronic properties like charge localization, spin density distribution and, in the case of magnetically ordered materials, spin structure. The pressure range covered is 0–14 Kbar in a temperature range 10–300 K. It is obtained with a He-gas high pressure system coupled to a closed-cycle refrigerator. First experiments were carried out on Fe and Ni to study the volume dependence of the magnetic field felt by positive muons implanted in those materials. The μ^+ occupy interstitial lattice positions and the field at the muon site is a measure of the interstitial spin density. It was found that the correction by volume dependence cannot remove the discrepancies noticed earlier between the measured and the calculated interstitial spin densities. In particular for iron a better theoretical model is clearly needed.

Experiments SC82 (CERN - Parma - Rutherford Collaboration) and SC95 (CERN - Leicester - Rutherford) apply the μSR technique to the study of molecular physics and chemistry. Implanted in a material, the μ^+ reacts and binds chemically as would a light-weight proton. The μSR signal behaviour can then be exploited to reveal the structure, dynamics or chemical properties of the molecule. Thus SC82 has completed a study of a muonated radical derived from a carbon-oxygen double bond; the carbonyl bond of acetone. In this paramagnetic molecule the unpaired electron is partially delocalised onto the oxygen atom. This makes the hyperfine coupling with the neighbouring muon extremely sensitive to the conformation of the molecule. Indications have been obtained for a muonic bonding analogous to hydrogen bonding.

Nucleus–Nucleus Reactions

Several Collaborations, CERN - Copenhagen - Grenoble - Lund - Saclay (SC83), Cagliari - CERN -

Strasbourg-Turin (SC90) and Darmstadt-Frankfurt-Heidelberg - Stony Brook (SC92), have studied pion production at incident energies well below the free NN threshold. Substantial cross-sections are observed far above a level that could be explained by taking into account the internal momenta of nucleons in the colliding nuclei. They would indicate a cooperative action of clusters of nucleons in the nuclei. A conclusion that is supported by the angular dependence of the pion yield and the apparent source velocity.

The emission of medium heavy fragments (heavier than typical evaporation products and lighter than fission fragments) has been studied by the Darmstadt-Heidelberg-Munster Collaboration (SC85). A suggestion that a liquid-gas phase transition in nuclear matter might be observed has stimulated interest in the production mechanism. The velocities of the light fragments ($A \leqq 3$) are centered at about half the beam velocity (~ 0.4 c) and the temperature in the region 10–20 MeV. This would be expected for the emission from the hot region where projectile and target overlap. For the medium heavy fragments ($A \geqq 6$) both the velocity and temperature show a smooth decrease with mass. From the results obtained with different targets, this behaviour may be explained by a direct momentum and energy transfer to a prefragment formed during the early stage of the collision.

Technical Developments

Electronics

An appreciable amount of the effort of the Electronics Research and Development Group was devoted to the UA1 collaboration. The electronic digitizers of the central detector have been equipped with double event buffering. The memory controllers are based on a large-scale integrated circuit, designed by the group. Other work for UA1 has been the design, production and commissioning of complex recording memories and interface modules (REMUS-VME-VMX). Within the VME-based buffering and processing system the MACVEE system has been developed together with the software team of UA 1. MACVEE is based on an Apple Macintosh personal computer connected to additional hardware in the VME crate via a private bus.

A close collaboration has been established with the LEP experiments on FASTBUS support and developments. As a result of this collaboration the development of a number of general-purpose modules has been started. The design of a basic FASTBUS system hardware and software has been completed and the range of devices produced by industry is gradually increasing.

The development of a read-out system for the Time Projection Chambers (ALEPH and DELPHI), in collaboration with outside laboratories, is progressing. The system is based on Flash Analogue to Digital Converters and is housed in FASTBUS. To cover the requirements of six detectors in DELPHI a high resolution (ns), wide range (μs) and high multiplicity time digitizer in FASTBUS is under development together with outside laboratories. A variety of devices has been designed for the uranium calorimeter and the transition radiation detector at NA 34.

More design, production, commissioning and maintenance work has been given, as usual, to most of the experiments presently setting up or running.

In collaboration with European manufacturers the Test and Instrumentation Group developed new switching power supplies for CAMAC. This project is being continued in view of a possible application to FASTBUS. A number of new electronics modules have been tested and standardized for the EP-Electronics Pool. This pool consists presently of about 38000 units and is used by CERN groups and visiting teams. In order to cope with the ever-increasing workload for maintenance and bookkeeping, more and more automation is applied.

Magnets and Mechanical Engineering

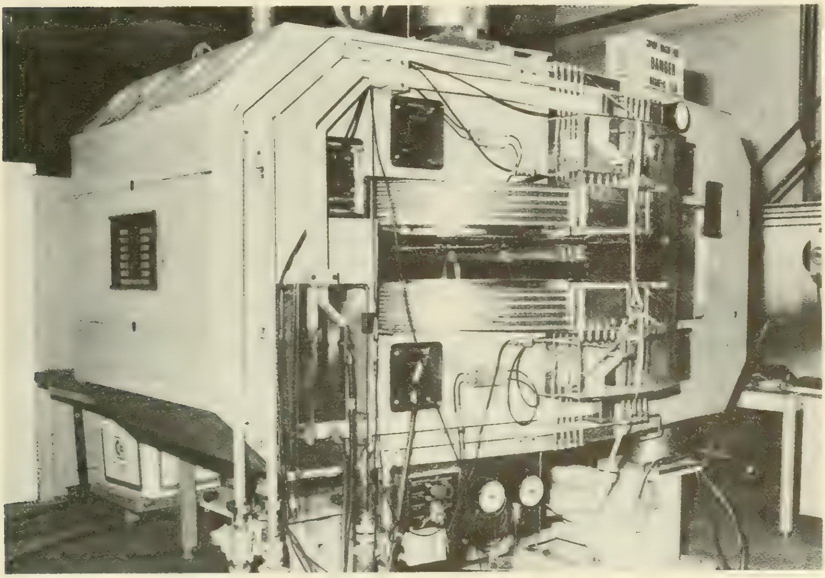
Careful technical planning and realization has been the basis of success for many experiments. Therefore the experience and ability of the technical groups are used extensively. Good sharing of the work between these groups, and between divisions, ensures efficiency. The spectrum of activities of these few groups is considerable.

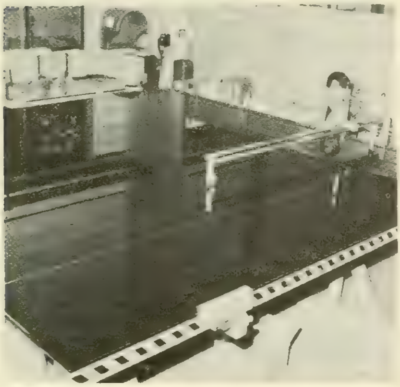
The Magnets and Beams Group (MB) has built and tested the 3 GHz modulator of experiment PS 189. Its precision spectrometer (Fig. 33) is near completion. The assembly of the 400 ton glass target of WA 79 has been studied and is now in progress (Fig. 34). Most of the group effort however went into the preparation of LEP experiments. Parts of the mechanical structure of the Time Projection Chamber (TPC) for ALEPH have been designed. The iron

Figure 33 — The PS189 spectrometer magnet during field mapping. (CERN-435.02.85)

Figure 34 — Application of adhesive during the construction of the 3.7 × 3.7 m² multilayer glass target of WA79 experiment. (CERN-136.11.84)

Figure 35 — Full scale model of 1/8 of the ALEPH experiment made for the study of cabling and piping. (CERN-288.02.85)





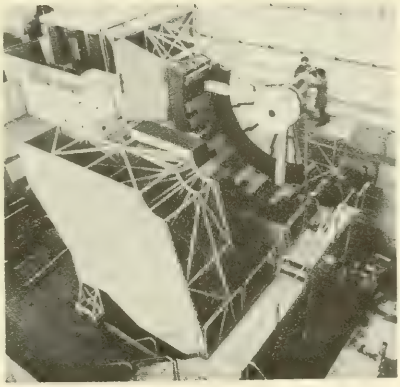
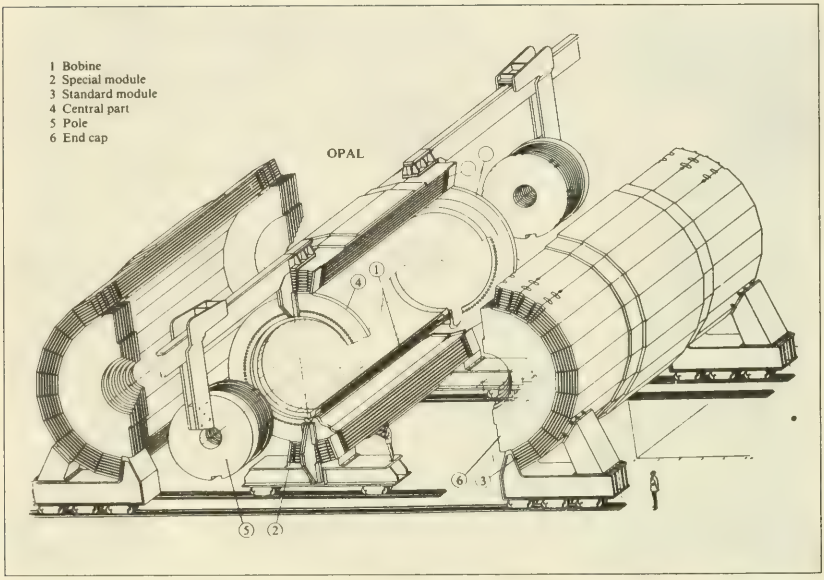


Figure 36 — Design study of the OPAL detector.



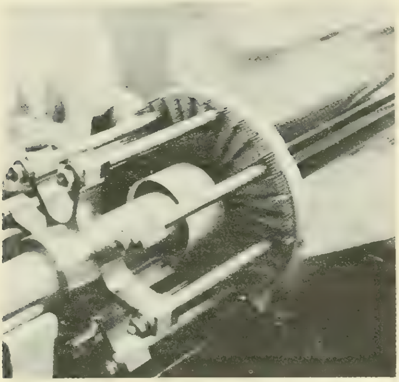
yokes of both ALEPH and DELPHI have been designed and most of the components are already ordered. Since there is a lack of computer programmes to calculate the magnetic field in 3 dimensions from the complicated boundary condition of these experiments, detailed field measurements on a scaled-down model have been made. The complicated infrastructure of the LEP experiments is studied and model work is pursued as well (Fig. 35).

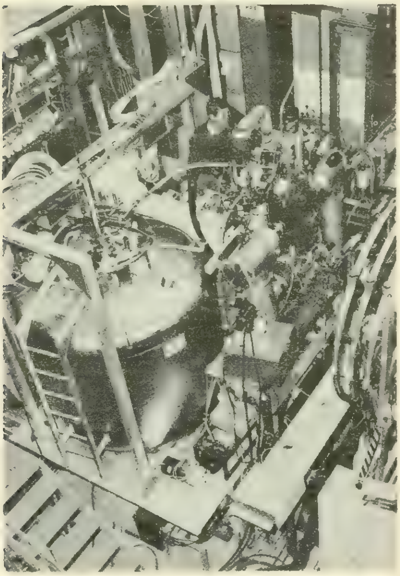
Some of these projects were carried out in very close collaboration with the Mechanical Engineering Group (ME). This group is executing the designs of the iron structures and the moving equipment of the LEP experiments (Fig. 36). Computer aided design (CAD) is used extensively for these studies. When a design is finished the group often follows up the projects to the end, by either making the object or studying fabrication procedures and dealing with outside firms. After manufacturing a test coil for the OPAL experiment, the tooling for the real coil is now being prepared. Among other experiments the ME group has been involved in WA 79, ISOLDE, LEAR, UA 1, and especially UA 6 constructing a calorimeter and the transition radiation detectors. The group is also engaged to maintain the 130 EP gas distribution systems for wire chambers.

The Technical Assistance Group (TA) is involved in experiment NA 31 building wire chambers and the big He-tank. A prototype RICH (Ring Imaging CHerenkov Detector) has been built for the RICH group to be used in UA 2. The TA-group is studying together with outside laboratories the RICH chambers for the endcaps and the parabolic mirrors for the barrel RICH of DELPHI. A major effort has been made to build the Mini Vertex Detector for UA 1 (Fig. 37). The group has done fabrication tests for the Central Electrode of the ALEPH-TPC and is preparing the manufacture of the field cages for the same detector. The winding of Polyester foils for the insulator of these cages has been the subject of extensive tests.

Figure 37 — Stretching the wires of the Mini-Vertex-Detector of UA1. (CERN-543.05.84)

Figure 38 — The 2 ℓ polarized target of NA2. (CERN-589.02.85)





Polarized Target Group

The largest polarized target in the world (2 litres of irradiated ammonia) developed by this group was set up at the experiment NA2 (Fig. 38) and ran successfully at a polarization of 80%. Another small polarized target was installed and running at LEAR. Final tests with a polarized beam source based on stable atomic hydrogen resulted in a 'record' stabilization rate of 10^{18} atoms/s, without any indication of vacuum-problems. In collaboration with the University of Rome the basic problems of the cryogenic layout and suspension of a gravitational antenna were studied. Also the design of the dilution refrigerator for the antenna was started. Some work for a cold silicon single-crystal calorimeter showed promising results.

Preparation of LEP Experiments

The preparation of the four LEP experiments has absorbed an increasing fraction of the resources of the EP and EF Divisions. To avoid duplication, most of this activity is reported in the EF section.

The building of these giant detectors has required an extensive programme of prototype investigation in addition to the construction of the final detectors.

Most of this work has been carried out in test beams from the PS and SPS machines. Some of the beam tests have rivalled full-scale SPS experiments in their size and complexity.

Here mention is made of just one major prototype investigation by each of the four experiments.

The ALEPH Collaboration has made detailed studies on the performance of a 90 cm long prototype Time Projection Chamber (TPC) to ensure that the full-scale chamber will give the best possible performance. They have succeeded in realizing their design goals with this prototype.

The DELPHI Collaboration has built and tested prototypes of their gas and liquid Ring Imaging CHerenkov (RICH) counters. They have succeeded in bringing their novel designs into operation.

The OPAL Collaboration has tested a full-size prototype section of their JET chamber, demonstrating that they can obtain the required spatial resolution.

The L3 Collaboration has tested two different arrays (5×5 and 3×3) of Bismuth Germanate (BGO) counters to determine their spatial and energy resolution.

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SPS EXPERIMENTS IN 1984

Experiment number	*Experiment*	*Collaboration*	*Status*
WA69	Photoproduction in the energy range 70–200 GeV	Bonn–CERN–Lancaster–Manchester–Rutherford–Sheffield	Data-taking
WA70	Study of direct photon events in hadronic collisions	Geneva–Glasgow–Liverpool–Milan–Neuchâtel	Data-taking
WA71	An experiment to study beauty production and lifetime in the upgraded Omega Prime Spectrometer	CERN–Genoa–Milan–Moscow–Paris–Rome–Santander–Valencia	Data-taking
WA75	An experiment to observe directly beauty particles selected by muonic decay in emulsion and to estimate their lifetimes	Bari–Brussels–CERN–Dublin–Japan–London–Rome–Turin	Completed 18.6.1984
WA76	Study of the mesons produced centrally in the reaction pp giving pp + X^0 and π^-p giving π^-p + X^0 at 340 GeV/c	Athens–Bari–Birmingham–CERN–Paris	Preparation
WA77	Search for direct production of gluonium states in high p_T π^-N collisions at 350 GeV/c	Athens–Bari–Birmingham–CERN–Paris	Data-taking
WA78	Search for the hadroproduction of B/anti-B pairs	Bari–Brussels–CERN–London–Rome–Turin	Data-taking
WA79	Study of neutrino–electron scattering at the SPS	Brussels–CERN–Hamburg–Moscow–Naples–Rome	Setting-up
WA80	Study of relativistic nucleus–nucleus collisions induced by ^{16}O projectiles	Darmstadt–Lawrence–Lund–Marburg–Munster–Oak Ridge–Warsaw	Preparation
WA81	Measurements of pair production under channelling conditions by 70–180 GeV photons incident on single crystals	Aarhus–CERN–Strasbourg	Preparation
WA1/2	Measurement of $\sin \theta_W^2$ in semileptonic neutrino/Fe interactions with high precision	CERN–Dortmund–Heidelberg–Saclay–Warsaw	Completed 30.8.1984
WA18/2	High precision measurement of the ratio between the neutral and charged current neutrino cross-sections	CERN–Hamburg–Amsterdam–Rome–Moscow	Completed 3.9.1984
NA1	Measurement of the photoproduction of vector and scalar bosons	Frascati–Milan–Pisa–Turin–Trieste–Westfield College	Completed 18.6.1984
NA2	Electromagnetic interactions of muons	Aachen–Annecy–CERN–Freiburg–Hamburg–Heidelberg–Lancaster–Liverpool–Marseilles–Mons–Oxford–Rutherford–Sheffield–Turin–Uppsala–Warsaw–Wuppertal–Yale	Data-taking
NA3	Direct photon production in hadron–hadron collisions at the SPS	CERN–Orsay–Palaiseau–Paris–Pisa–Saclay	Completed 3.9.1984
NA4	Inclusive deep-inelastic muon scattering	Bologna–CERN–Dubna–Munich Saclay	Data-taking
NA10	High resolution study of the inclusive production of massive muon pairs by intense pion beams	CERN–Naples–Palaiseau–Strasbourg–Zurich	Data-taking
NA12	Study of π^-p interactions with neutral final states	Annecy–Brussels–Los Alamos–Serpukhov	Completed 18.6.1984
NA14	Photoproduction at high energy and high intensity	Athens–CERN–London–Orsay Palaiseau–Paris–Saclay–Southampton–Strasbourg–Warsaw	Completed 3.9.1984
NA24	Investigation of deep-inelastic scattering processes involving large p_T direct photons in the final state	Bari–Freiburg–Moscow–Munich	Data-taking
NA27	An experiment to measure accurately the lifetime of the $D^0D^*F^*\Lambda_c$ charm particles and to study their hadronic production and decay properties	Aachen–Bombay–Brussels–CERN–Duke–Genoa–Japan–Liverpool–Madrid–Mons–Oxford–Padua–Paris–Rome–Rutgers–Rutherford–Serpukhov–Stockholm–Strasbourg–Tennessee–Trieste–Turin–Vienne–Zeuthen	Completed 1.6.1984

SPS EXPERIMENTS IN 1984 (Cont.)

Experiment number	*Experiment*	*Collaboration*	*Status*
NA30	Precision determination of the lifetime of the neutral pion	Ames–CERN–Chicago–Lund–Paris	Completed 1.6.1984
NA31	Measurement of $\|\eta_{00}\|^2/\|\eta_{+-}\|^2$	CERN–Dortmund–Edinburgh–Orsay–Pisa–Siegen	Data-taking
NA32	Investigation of charm production in hadronic interactions using high-resolution silicon detectors	Amsterdam–Bristol–CERN –Cracow–Munich–Rutherford	Data-taking
NA33	An experimental study of single-vertex e^+e^- pair creation in a crystal	Albany–Annecy–Frascati–Lyon	Data-taking
NA34	Lepton production	Brookhaven–CERN–Heidelberg–London–Los Alamos–Lund–Montreal–Moscow–Novosibirsk–Pittsburgh–Rutherford–Saclay–Syracuse–Tel-Aviv	Preparation
NA35	Study of relativistic nucleus–nucleus collisions induced by ^{16}O projectiles	Athens–Cracow –Darmstadt –Frankfurt–Heidelberg–LBL–Marburg–Texas –Warsaw–Zagreb	Preparation
NA36	The production of strange baryons and anti-baryons with relativistic light ion collisions at the CERN SPS	Bergen –Birmingham –Lawrence Berkeley Lab.–Oxford	Preparation
NA14/2	A program of heavy flavour photoproduction	Athens–CERN –London–Orsay –Palaiseau–Paris–Saclay –Southampton –Strasbourg–Warsaw	Test
NA34/2	Study of high energy densities over extended nuclear volumes via nucleus–nucleus collisions at the SPS	Brookhaven–CERN–Heidelberg–Los Alamos–Lund–Montreal–Moscow–Novosibirsk–Pittsburg–Saclay–Syracuse–Tel-Aviv	Preparation
UA1	A 4π solid-angle detector for the SPS used as a proton–antiproton collider at a c.m. energy of 540 GeV	Aachen–Amsterdam–Annecy–Birmingham CERN–Harvard–Helsinki–Kiel–London–Padua–Paris–Riverside–Rome–Rutherford–Saclay–Vienna–Wisconsin	Data-taking
UA2	Study of antiproton–proton interactions at 540 GeV c.m. energy	Bern–CERN–Copenhagen–Heidelberg–Orsay–Pavia–Perugia–Pisa–Saclay	Data-taking
UA4	Measurement of the elastic scattering in the Coulomb interference region at the antiproton-proton collider	Amsterdam–CERN–Genoa–Naples–Palaiseau–Pisa	Data-taking
UA5/2	An exploratory investigation of proton antiproton interaction at 800–900 GeV cm energy at the SPS collider	Bonn–Brussels –Cambridge –CERN–Stockholm	Preparation
UA6	An internal hydrogen jet target in the SPS to study inclusive electromagnetic final states and Λ production in $p\bar{p}$ and pp interactions at 22.5 GeV c.m.	CERN–Lausanne –Michigan –Rockefeller	Setting-up
EMU01	Study of particle production and nuclear fragmentation in collisions of ^{16}O beams with emulsion nuclei at 13–200 GeV	Jaipur–Jammu–LBL–Lund–Ottawa–Seattle	Preparation
EMU02	Search for fractionally charged nuclei in high-energy oxygen-lead collisions	U.C. Berkeley–CERN	Preparation
EMU03	Interactions of ^{16}O projectile and its fragments in nuclear emulsion at about 50 and 225 GeV/c	Cairo	Preparation

PS EXPERIMENTS IN 1984

Experiment number	*Experiment*	*Collaboration*	*Status*
PS170	Precision measurements of the proton electromagnetic form factors in the time-like region and vector meson spectroscopy	Ferrara–Padua–Saclay–Turin	Data-taking
PS171	Study of $\bar{p}p$ interactions at rest in a hydrogen gas target at LEAR (ASTERIX)	CERN–Mainz–Munich–Orsay–Vancouver (TRIUMF)–Victoria–Zurich	Data-taking
PS172	$\bar{p}p$ total cross-sections and spin effects in $\bar{p}p \rightarrow K^+K^-$, $\pi^+\pi^-$, above 200 MeV/c (LEAR)	Amsterdam–Geneva–London–Surrey–Trieste	Data-taking
PS173	Measurement of $\bar{p}p$ cross-sections at low $\bar{p}$ momenta	Heidelberg (MPI + Univ.)	Data-taking
PS174	Precision survey of X-rays from $\bar{p}p$ ($\bar{p}d$) atoms using the initial LEAR beam	Amsterdam–Birmingham–Rutherford–Williamsburg	Data-taking
PS175	Measurement of the antiprotonic Lyman and Balmer X-rays of $\bar{p}$H and $\bar{p}$D atoms at very low target pressures	Karlsruhe	Data-taking
PS176	Study of X-ray and γ-ray spectra from antiprotonic atoms at the slowly extracted antiproton beam of LEAR	Basle–Karlsruhe–Stockholm–Strasbourg–Thessaloniki	Data-taking
PS177	Search for heavy hypernuclei at LEAR	Amsterdam–CERN–Darmstadt–Grenoble–Orsay–Saclay–Uppsala–Warsaw	Data-taking
PS178	Study of antineutron production at LEAR	Cagliari–Padua–Turin	Data-taking
PS179	Study of the interaction of low-energy antiprotons with H^2, He^3, He^4, Ne-nuclei using a streamer chamber in a magnetic field	Dubna–Frascati–Padua–Pavia–Turin	Data-taking
PS180	Search for neutrino oscillations at the CERN PS using BEBC	Athens–Padua–Pisa–Wisconsin	Completed 9.8.1984
PS182	Investigations on baryonium and other rare $\bar{p}p$ annihilation modes using high-resolution π^0 spectrometers	Basle–Stockholm–Thessaloniki	Data-taking
PS183	Search for bound $\bar{N}$ N states using a precision gamma and charged pion spectrometer at LEAR	Athens–Irvine–Karlsruhe–New Mexico–Pennsylvania–Strasbourg	Data-taking
PS184	Study of $\bar{p}$-nucleus interaction with a high-resolution magnetic spectrometer	Grenoble–Saclay–Strasbourg–Tel-Aviv	Data-taking
PS185	Study of threshold production of hyperon–antihyperon pairs in antiproton–proton interactions at LEAR	Carnegie-Mellon–CERN–Erlangen-Nuernberg–Freiburg–Los Alamos–Saclay–Uppsala–Vienna	Data-taking
PS186	Nuclear excitations by antiprotons and antiprotonic atoms	Munich (Technical Univ.)	Data-taking
PS187	A good statistics study of antiproton interactions with nuclei	Los Alamos–Grenoble	Completed 17.6.1984
PS188	Measurements of channelling radiation and its polarization, X-ray excitation, together with deviations from Landau distributions	Aarhus–CERN–Strasbourg	Data-taking
PS189	High precision mass measurements with a radiofrequency mass spectrometer – Application to the measurement of the proton–antiproton mass difference	CERN–Orsay	Preparation
PS191	Search for decays of heavy neutrinos with the PS beam	Annecy–Athens–CERN–Paris–Rome	Completed 9.8.1984
PS194	Measurements of the ratio between double and single ionization of helium for antiprotons	Aarhus–CERN–Stockholm	Preparation

SC EXPERIMENTS IN 1984

Experiment number	*Experiment*	*Collaboration*	*Status*
ISOLDE	ISOLDE programme	ISOLDE	Data-taking
IS 10	Determination of the mass of the electron-neutrino from experiments on electron capture beta-decay (EC)	Aarhus–CERN–Lund–Roskilde	Data-taking
IS20	Mössbauer studies of implanted impurities in solids	Aarhus–CERN	Data-taking
IS30	PAC experiments at ISOLDE	Berlin–CERN	Data-taking
IS40	ABMR experiments at ISOLDE	Göteborg–CERN	Data-taking
IS60	Continuation of mass determinations through a double focusing mass spectrometer on line with ISOLDE	Orsay	Data-taking
IS70	Continuation of atomic spectroscopy on alkali isotopes at ISOLDE	CERN–Orsay	Data-taking
IS80	Study of nuclear moments and mean-square charge radii by collinear fast-beam laser spectroscopy	Göteborg–Mainz–CERN	Data-taking
IS81	Laser spectroscopy at $Z = 50$	CERN–Darmstadt–Mainz	Preparation
IS82	Multiphoton ionization detection in collinear laser spectroscopy of ISOLDE beams	CERN–Mainz	Preparation
IS90	Study of doubly-closed shell nucleus ^{132}Sn and its valence nuclei	Bergen–CERN–Darmstadt–Göteborg–Jülich–Kingston–Stockholm	Completed Nov. 1984
IS100	Studies of stable octupole deformations in the radium region	Bergen–Chalmers–Mainz–Warsaw	Data-taking
IS110	Nuclear orientation studies and measurements of magnetic moments of radon isotopes	CERN–Princeton	Preparation
SC65	Local magnetic fields in ferromagnetics studied by positive muon precession	CERN–Grenoble–Uppsala	Data-taking
SC68	Muonic chemistry in condensed matter	Parma	Data-taking
SC76	Impurity trapping of positive muons in metals	CERN–Geneva–Jülich–Uppsala	Data-taking
SC81	Formation and interaction of muonic in insulators and semiconductors	Parma–Rutherford	Data-taking
SC82	μSR in organic and free radical chemistry	CERN–Parma–Rutherford	Completed March 1984
SC83	Study of particle production in ^{12}C induced heavy ion reactions at 86 MeV/N	CERN–Copenhagen–Grenoble–Lund–Saclay	Data-taking
SC85	Element distribution and multiplicity of heavy fragments	Darmstadt–Heidelberg–Münster	Completed March 1984
SC86	Study of nuclear collisions of 86 MeV/N ^{12}C with heavy targets by collection of the heavy recoil nuclei	Bordeaux	Completed March 1984
SC87	Study of target fragmentation in the interaction of 86 MeV/N ^{12}C with tantalum, bismuth, and uranium	Berkeley-Oregon–Studsvik	Completed March 1984
SC88	Study of reaction mechanism in the interaction 86 MeV/N ^{12}C with heavy targets	Grenoble–Lyons	Completed March 1984
SC92	Subthreshold production of neutral pions in heavy ion collisions	Darmstadt–Frankfurt–Heidelberg–Stony Brook	Data-taking
SC93	μSR measurements under high pressure and at low temperatures	Grenoble–Munich–Uppsala	Data-taking
SC95	Muons and muonium in molecular physics	CERN–Leicester–Rutherford	Data-taking
SC96	600 MeV simulation of the production of cosmogenic nuclides in meteorites by galactic protons	Ahmedabad–Bordeaux–Cologne–Jülich–Mainz–Zurich	Completed Dec. 1984

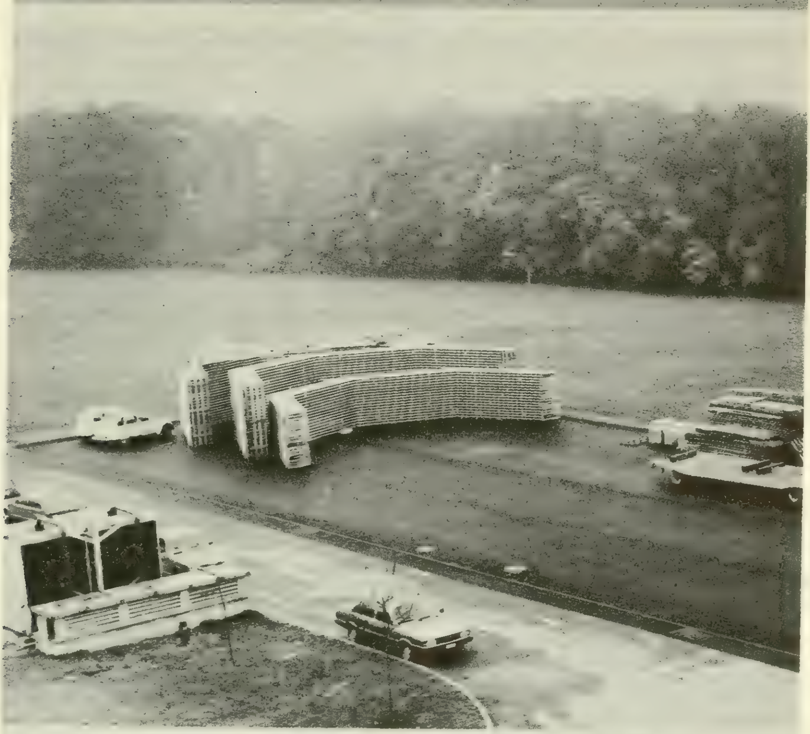
ISR EXPERIMENTS IN 1984

Experiment number	*Experiment*	*Collaboration*	*Status*
R704	Charmonium spectroscopy at the ISR using an antiproton beam and a hydrogen jet target	Annecy–CERN–Genoa–Lyons–Oslo–Rome–Turin	Completed 18.6.1984

LEP EXPERIMENTS in preparation in 1984

The ALEPH Detector	Athens – Bari – Beijing – CERN – Clermont-Ferrand – Copenhagen – Dortmund – Edinburgh – Egham – Frascati – Glasgow – Heidelberg – Lancaster – London – Marseilles – Munich – Orsay – Palaiseau – Pisa – Rutherford – Saclay – Sheffield –Siegen – Trieste – Wisconsin
OPAL Collaboration	Birmingham – Bologna – Bonn – Cambridge – Carleton – CERN – Chicago – Freiburg – Heidelberg – Israël – London (Birkbeck + QMC + UC) – Manchester – Maryland – Ottawa – Rehovot (Weizmann Inst.) – Rutherford – Saclay – Tel-Aviv – Tokyo
L3 Experiment	Aachen (I + III) – Amsterdam – Annecy – Beijing – Bombay – Budapest – CALTEC – Carnegie-Mellon – CERN – Florence – Frascati – Geneva – Harvard – Hawaii – Hofei– John Hopkins Univ. – Lausanne – Lund – Lyons – Madrid – Michigan – MIT – Moscow – Munich – Naples – Northeastern – Ohio State Univ. – Oklahoma Univ. – Princeton – Rome – Rutgers – Siegen – Yale – Zeuthen – Zurich
DELPHI	Ames – Amsterdam (NIKHEF) – Athens (Univ. + Nat.Tech.Univ.) – Belgium – Bergen – Bologna – CERN – Copenhagen – Cracow – Dubna – Genova – Helsinki – Karlsruhe – Liverpool – Lund – Milan – Orsay – Oslo – Oxford – Padoua – Paris (Coll. de France + LPNHE) – Rome – Rutherford – Saclay – Santander – Serpukhov – Stockholm – Strasbourg – Trieste – Turin – Uppsala – Valencia – Vienna – Warsaw – Wuppertal

Experimental Physics Facilities Division



Storage lot for the LEP experiment L3 magnet half-turns near Hall 867. (CERN-031.11.84)

Experimental Physics Facilities Division

Introduction

The year 1984 was marked at CERN by the award of the Nobel prize in physics for the discovery in 1983 of the W and Z particles, the carriers of the weak force. Technical support groups from EF Division have participated in all phases of the design, construction and operation of the two large experiments concerned, UA1 and UA2, including the successful programme of operations in 1984, and will continue to play their part in the improvement programmes during the next years. The division is also involved in the preparation of experiments UA4 and UA5, scheduled for data-taking in 1985 with the SPS collider operating in a new pulsed mode at 450 + 450 GeV.

Another important aspect of 1984 was the termination of the CERN bubble chamber experiments programme, an important concern of this division for the past 25 years. During the summer the last two bubble chamber runs took place, as the small high resolution chamber LEBC operating as vertex detector in the EHS spectrometer completed the final run of a charm decay experiment, and the last picture taken in BEBC terminated the neutrino oscillation experiment in the PS neutrino beam.

Thus with the increasing support to LEP projects, 1984 has been a year of transition for EF. Although support for fixed-target experiments has continued, greater emphasis has been applied to the design and the construction work of the four LEP experiments ALEPH, DELPHI, L3 and OPAL and additional help given in the preparation of the LEP accelerator. A special effort went into the development of superconducting accelerating cavities.

In the fixed-target field, EF ran the Omega spectrometer and the superconducting magnets in the West Area and North Area beam lines. Construction proceeded of the liquid argon photon calorimeter for the new CP violation experiment and a new group, working with a corresponding EP Division team, made a start on the detector for the new lepton production experiment.

Work has started on the improved neutrino wide-band beam for the CHARM II experiment and on the new neutrino detector for this experiment. In collaboration with EP Division, development work has continued on silicon microstrip telescopes and has started on a novel scintillating-fibre detector.

The former ISR experiment support group joined EF Division in order to prepare the infrastructure of the experimental areas for the four LEP experiments. In close collaboration with corresponding groups in EP Division and in outside laboratories, LEP detector groups in EF have completed the design work on these four LEP experiments. Construction of major components has begun and a series of 'milestone' prototypes were successfully tested. At the same time the development of radio-frequency superconducting accelerating cavities for the LEP accelerator progressed in an encouraging fashion and prototypes of 350 MHz cavities for LEP are being tested.

EF is also involved in various aspects of the construction programme of the LEP machine, for example in the vacuum system, in bending magnet measurement and quality control and in developing special instruments for the geodetic survey work.

Detectors for Fixed-Target Experiments

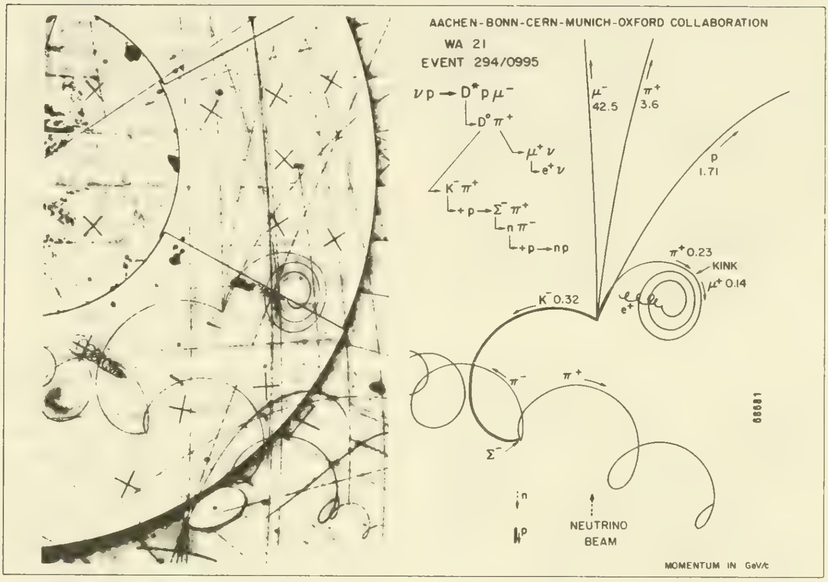
The three large detector systems BEBC, European Hybrid Spectrometer (EHS) and Omega were employed in fixed-target physics in 1984. BEBC, in completing the neutrino oscillation experiment has come to the end of its physics programme and has now been shut down, while EHS with experiment NA27 has completed its last run with a bubble chamber as vertex detector.

Meanwhile, work continued on the liquid argon photon calorimeter for the CP violation experiment NA31, on various components for the newly-approved experiment NA34 currently being set up in the former NA3 area, and on the evaluation of data of experiment WA44, the search for free quarks.

BEBC

During the summer months the Big European Bubble Chamber BEBC (volume 35 m^3, with a 3.5 tesla superconducting magnet) completed the second and final part of the neutrino oscillation experiment PS180. BEBC was filled with a 73 mole per cent neon-hydrogen mixture, and took 567000 neutrino pictures together with 95000 cosmic ray calibration pictures. With the 19 GeV PS beam it was possible to establish a record chamber expansion rate greater than one expansion every three seconds averaged over the whole run, an impressive performance for so big a bubble chamber.

Figure 1—A late WA21 photograph taken in BEBC filled with hydrogen and exposed to the wide-band neutrino beam. This event, analysed on ERASME, is one of the first showing unambiguously charm production by a neutrino. (CERN–68647)



The completion of this experiment signalled the end of the BEBC scientific programme. Originally designed for neutrino physics at PS energies by a France—West Germany—CERN collaboration starting work in late 1965, and financed equally by these partners, BEBC took its first photographs in PS hadron beams in March 1973. After the SPS start-up BEBC was exposed from early 1977 until the end of 1983 to SPS hadron and neutrino beams at much higher energies (up to 450 GeV). The addition of the External Muon Identifier (EMI), the Internal Picket Fence (IPF), the External Particle Identifier (EPI) and a Track-Sensitive Target (TST) converted BEBC into a hybrid detector. In addition, during tests of holographic techniques, tracks were recorded for the first time in a large detector.

In all with some 13 million expansions BEBC furnished 6.3 million pictures for 22 experiments, mostly with four or five separate views on the BEBC 70 mm film, of which 3000 km were used.

The superconducting magnet, storing more magnetic energy than any other magnet in the world, was cold for 86500 hours (that is almost 10 years total time), and was operational at full current for 25000 hours, being energized for the last time on the occasion of the 1984 CERN Open Day. During a total operating time of about 38 months the chamber was run with liquid hydrogen, deuterium, and with neon-hydrogen mixtures of various proportions.

Almost 50 laboratories all over the world have participated in the analysis of BEBC film. Not counting contributions to conferences or theses, 108 papers have so far been published in scientific journals; since not all BEBC film has yet been scanned and analysed, more are expected. At least 550 researchers have participated in experiments using BEBC, a number to be compared with the 2000 or so physicists currently making use of the CERN research facilities.

Dismantling of BEBC is under way and will be finished during 1985.

Omega Spectrometer

The Omega spectrometer is made up of a set of wire and drift chambers in and around the 1.8 tesla field of a superconducting magnet, and of Cherenkov counters and counter hodoscopes, all backed up by powerful software for event reconstruction. Various experiments use the basic detector system, differing in the choice of beam (hadrons up to 450 GeV; photons up to 200 GeV), in the trigger system for event selection and in 'private' detectors of the different collaborations, which complement the basic system. These private detectors usually remain at Omega and are used later by other experiments. The new RICH (Ring Imaging CHerenkov counter), constructed by the Rutherford-Appleton Laboratory, is an example of such a private detector. It will in future be operated by EF Division and the Omega group is carrying out some improvements on the electronics and on the gas system.

Having made a start the previous year in setting up, the four new experiments

- WA69 photo-production in the energy range 70-200 GeV
- WA70 study of direct photon events in hadronic collisions
- WA71 an experiment to study beauty production and lifetime
- WA77 search for the direct production of gluonium states

have taken much data in optimized experimental conditions. In particular, WA70 and WA77 successfully selected interesting events from more than one million interactions per second. At such a rate when each interaction generates thousands of data words, the time necessary for event selection and for event recording (dead time) becomes a problem. New developments in event selection electronics and the use of a MICE—MICro-programme Engine (a fast PDP11 emulator developed by DD Division) helped in keeping the dead time at an acceptable level.

European Hybrid Spectrometer with the Bubble Chamber LEBC

The European Hybrid Spectrometer (EHS) comprises a wide range of detectors for identification and momentum measurement of charged particles and for the determination of the energy of the neutrals. In 1984, EHS was operated with the LExan Bubble Chamber (LEBC), sometimes also referred to as HOLEBC, HO standing for High Optical resolution.

In Spring, EHS completed the charm experiment NA27, taking in this third run 1.64 million pictures of proton-proton interactions at 400 GeV, complemented by spectrometer data. Totals of 0.98 million pictures of pion-proton interactions, corresponding to a sensitivity of 15.8 events per microbarn, and 2.4 million pictures of proton–proton interactions, corresponding to 60 events per microbarn, have been gathered.

Completion of experiment NA27 marked the end of operation of LEBC at CERN. In total, this bubble chamber has, in the past years, accumulated nearly 5 million pictures for experiments NA13, NA16 and NA27. In summer, the chamber and its ancillary equipment were dismantled and prepared for shipment to the Fermi National Accelerator Laboratory (Fermilab) in the USA, where it will serve in another charm experiment (E743) with 800 to 1000 GeV proton beams supplied by the Tevatron.

Planning was started for adapting the configuration of EHS for the oxygen-ion experiment NA36, scheduled for 1986.

Detectors for Proton–Antiproton Collider Experiments

The proton–antiproton collider experiments UA1, UA2, UA4 and UA5 have been taking data, from time to time, since the second half of 1981.

New physics results from proton-antiproton collider experiments are described in the EP chapter of this Annual Report, while some aspects of the new accelerator technique are presented in the PS chapter.

Having in the past been involved in the design, construction and operation of the detectors, EF Division is now participating in the respective upgrading programmes of experiments UA1 and UA2, and in some improvements to UA4 and UA5.

Experiment UA1

The central detector of experiment UA1 is a cylindrical drift chamber in a magnetic field of 0.7 tesla, around which is a scintillator calorimeter for electromagnetic shower detection ('gondolas'). Hadron calorimetry is integrated into the magnet yoke and there are also muon chambers and other equipment.

Detector improvements carried out in the first part of the year were principally the incorporation of new walls of magnetized iron, equipped with Iarocci tubes, for additional filtering of muons, and the installation of complementary muon chambers in the forward direction. The central detector electronic system has been equipped with a double buffer permitting parallel read-out, to allow the detector to operate efficiently at the increasing luminosity of the collider. A microvertex chamber, a pressurized cylindrical drift chamber directly surrounding the beam tube of the accelerator, is in preparation. Other development work in hand concerns the envisaged replacement of the present electromagnetic shower detector by a calorimeter incorporating uranium-238 ('depleted uranium') as the predominant conversion material.

Experiment UA2

The detector of experiment UA2 consists of a vertex detector (4 proportional and 2 drift chambers and a pre-shower counter for track pattern recognition and ionization measurements), a highly-segmented electromagnetic calorimeter (lead glass) without magnetic field, hadron calorimeters in the central region, and magnetic spectrometers (toroids) in the forward and backward cones.

The improvement programme, approved in 1984 by the Research Board, mainly envisages the closure of the calorimeters in the forward direction. Thus the forward spectrometers will be replaced by segmented end-cap calorimeters (lead-scintillator and iron-scintillator sandwiches for electromagnetic and hadronic showers). The design of these calorimeters has been completed.

Tests have been carried out in view of the planned incorporation, in 1985, of a silicon pad counter in the vertex detector. A new beam tube of reduced diameter, in beryllium, will be provided by SPS Division.

A scintillating-fibre detector for the upgraded vertex detector appears to be feasible (see paragraph Detector Developments). Further improvements planned for the start-up of the new antiproton accumulator ACOL in 1987 are a microvertex chamber, a cylindrical transition radiation detector, and end-cap pre-shower chambers.

A Ring Imaging CHerenkov detector (RICH) has been installed in one sector (1/12 of the acceptance) of the magnetic spectrometers, to explore the experimental possibilities of this new detector system.

Experiments UA4 and UA5

Experiments UA4 and UA5 are situated along with UA2 at intersection point 4 of the SPS collider. A small amount of technical support has been provided to experiment UA4 (elastic scattering) which will make use of wire chambers and silicon microstrip devices in the Roman Pots adjacent to the UA2 area.

The detector of experiment UA5 consists essentially of two large streamer chambers (each 6 m × 1.25 m × 0.5 m), a set of trigger hodoscopes, and six stereoscopic cameras which take pictures of the chambers via image intensifiers. Its salient feature is the potential for a rapid visual survey of complex events. The detector has already been used for proton–antiproton physics at 270 + 270 GeV.

It is intended to extend these investigations to much higher energies, 450 + 450 GeV, with the SPS collider operating in a new pulsed mode. Data taking for this second-generation experiment, UA5/2, will start in March 1985. The detector has been revised for this run: a new lead converter has been installed between the beam tube of the accelerator and the upper streamer chamber, replacing the former lead-glass converter located inside the chamber.

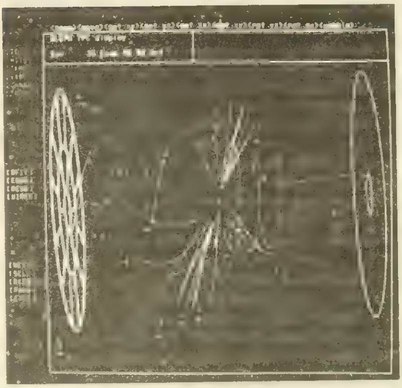
LEP Experiments

In November 1982, the Research Board, following the recommendation of the LEP Experiments Committee, approved four experiments for LEP:

ALEPH (Apparatus for LEp PHysics),
OPAL (Omni-Purpose Apparatus for Lep),
L3 (Letter of intent number 3), and
DELPHI (DEtector with Lepton, Photon and Hadron Identification).

ALEPH and OPAL are sometimes referred to as classical experiments, because their layout conforms to some extent with trends at existing colliders. ALEPH plans to use a time-projection chamber as the central detector and a lead and wire-chamber sandwich calorimeter as the electromagnetic shower counter, the two surrounded by the superconducting coil of the magnet, whose iron yoke is equipped with Iarocci tubes and which doubles as a hadron calorimeter. In OPAL, the central detector will be a cylindrical drift chamber and the electromagnetic shower counter a lead-glass calorimeter, with the coil of the magnet in the annular space between them.

Figure 2 — Track reconstruction of a 2-jet 'Monte-Carlo' event in the TPC. This reconstruction requires one second on an IBM-168 computer



L3 emphasises accurate tracking and high precision in energy measurement of leptons, aiming at a mass resolution better than 2% in dilepton final states. Notable features of the experiment are the enormous size of the magnet and the muon detectors, and the envisaged use of a calorimeter incorporating 12000 Bismuth Germanium Oxide (BGO) crystals for electromagnetic shower detection.

DELPHI proposes to employ the novel technique of Ring Imaging CHerenkov counters (RICH) for better hadron identification. The RICH detectors will be installed around the central detector, a time-projection chamber. A High-density Projection Chamber (HPC) will serve for electromagnetic calorimetry. All these detectors are mounted inside the superconducting magnet coil.

EF Division is, together with EP Division, involved in all four experiments, and the two divisions are jointly developing and constructing particular components. EF Division is, in particular, providing general technical support, such as co-ordination of detector design, preparation of the CERN infrastructure, elaboration of the installation programme, study of safety questions, and so on. A LEP interface group was formed in EF early in 1984 with particular responsibility for all installation problems concerning these experiments.

Experiment ALEPH

EF Division is involved in work on the cryogenic system for the superconducting magnet (together with CEN Saclay) and with EP Division and many of the laboratories of the collaboration in development work on the iron yoke for the magnet and on the prototype Time-Projection Chamber (TPC) of the central detector. A particular EF interest is the electrostatic field cage which establishes an extremely uniform electrostatic field over the volume of the TPC.

The coil and the magnet yoke have been ordered as have tools and materials for the construction at CERN in 1985 of the field cage; all other important components of the detector are in the tooling-up stage for the massive construction effort in the laboratories of the collaboration.

A substantial effort was devoted to prototype tests. Two examples may illustrate this.

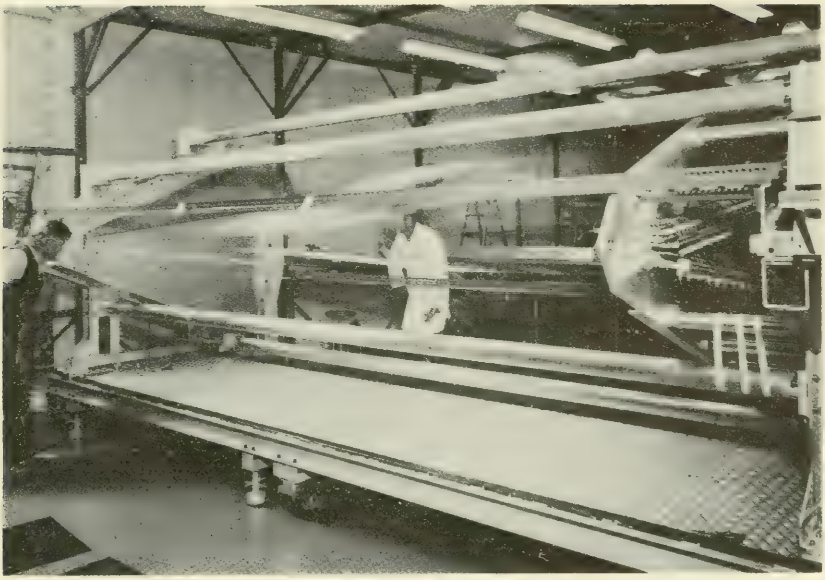
A key problem is discriminating between hadrons and electrons. Beam tests show that by comparing the energies deposited in a prototype module of the electromagnetic calorimeter with the momentum measured in the TPC, rejection ratios of 1/1000 are possible thanks to the exceptionally fine granularity of this device.

Another key problem concerns the systematic error of a TPC. In a TPC, particle tracks are measured by drifting the electrons produced by the track particles in a gas over a distance of up to 2 m to a receptor plate at the end of the chamber, where the positions and arrival times of the electrons are measured, permitting reconstruction of the track in space. Along the drift path, distortions are introduced by irregularities in the electric and magnetic fields, which must be accurately known to arrive at the desired precision of better than 0.1 mm. The drifting was studied extensively in a TPC prototype (known as TPC 90) with very good results. Since the original TPC (a chamber used at SLAC, USA) experienced some drifting problems, these results are important and reassuring.

A calibration system for the TPC, making use of three light beams derived from a single laser beam, is being developed.

A large effort is engaged in the very complex electronics and computing problems posed by the large number of data channels of ALEPH. Several monolithic circuits are under development. The on-line electronics, which must monitor the apparatus and control the flow of data, is absorbing a big effort, as is the development of the off-line software which must reduce the raw data of 10^5 bytes per event to the ultima-

Figure 3—Assembly of the full size prototype of the OPAL Jet Chamber. (CERN-127.07.84)



tely relevant quantities, for example the momentum of a particle observed.

A full-size model of one-eighth of ALEPH has been constructed, largely to study the problem of accommodating some 12000 cables totalling 355 km.

Experiment OPAL

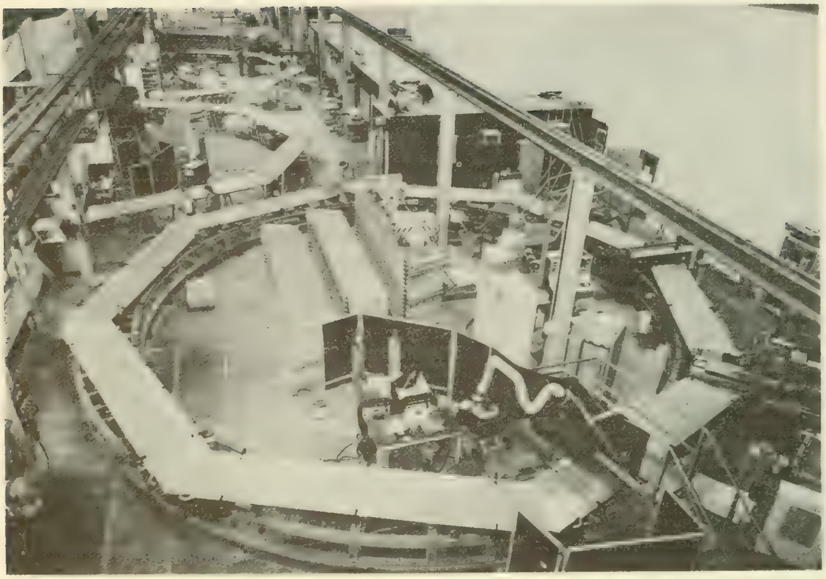
In preparing the OPAL experiment the activities of EP and EF Divisions concern mainly the magnet, the central detector and the support structure for the lead-glass barrel calorimeter.

The complete iron yoke for the magnet (weighing about 2400 tons) has been ordered, and the design of the coil has been completed.

After tendering, the component parts of the lead-glass calorimeter have been partially ordered.

Concerning the central detector, two 'milestones' set by the LEP Experiments Committee have been passed. First a prototype Z chamber (which measures the axial z co-ordinates of tracks) has worked very satisfactorily in a magnetic field of up to 1 tesla. Secondly a full-size prototype of two complete sectors of the Jet chambeı (which measures radial and azimuthal co-ordinates) has been built. The successful operation of this prototype has proven that the design of the OPAL Jet chamber with a wire length of 4 m is technically sound. In a preliminary analysis, tracking accuracies between 100 and 150 micrometers for drift distances up to 16 cm have been obtained and the relative z resolution is of the order of 1%. Particles are identified by sampling their ionization up to 160 times. A resolution in dE/dx of 3 to 4% has been obtained. A detailed analysis of the shape of the chamber pulses, yielding a double track resolution of 2 mm, is achieved by using FADC's (Flash Analogue-Digital Converters). Microprocessors working in parallel have been shown able to cope with the enormous data flow produced by this technique.

Figure 4 — L3 coil factory in Hall 867 of the Prévessin site. In the foreground 6 cm thick, 90 cm wide aluminium plates are joined by electron-beam welding to form octogonal half turns. At the work stations in the background the weldings are checked and cooling pipes connected. (CERN-037.11.84)



In conclusion all results obtained so far are well in accordance with the expected values, and the construction phase of the central detector has started.

Experiment L3

In 1984 the design of most of the L3 detectors was finalized. Construction of the L3 magnet coil started and major orders were placed for the magnet poles. In addition, 4 cranes and 4000 of the 12000 BGO crystals were ordered. The assembly and installation sequence of the detector was studied in detail and solutions adopted for many infrastructure problems.

A detailed stress analysis and discussion with potential manufacturers of the 35 m long, 4.4 m wide detector support tube, led to a simplified design combining cheaper construction and faster installation with smaller deflections under the weights of the detectors. At the same time the mechanical design and installation sequence of the set of detectors inside and around the support tube were examined in order to minimize the installation time. The EF-L3 design team also helped to finalize the mechanical structure of the barrel part of the hadron calorimeter, which will consist of 144 stainless steel housings, arranged in 9 rings around the BGO electromagnetic shower counter. Each module will contain 58 uranium plates 5 mm thick, shielded on both sides by 1 mm of copper. Read-out is by wire chamber planes grouped into more than 20000 electronic 'towers'.

The infrastructure design work concentrated on the final definition of civil engineering parameters for the underground experimental area and surface buildings. A 1/20th-scale wooden model was built to better understand space requirements for services and shielding problems. In particular, shielded counting houses situated at both ends of the experimental cavern with independently shielded accesses were developed. The final arrangements of the cranes in the experimental

Figure 5 — Barrel RICH for DELPHI. Rings produced by a pion from a liquid radiator (large ring) and a gaseous radiator in the same drift chamber detector filled with methane-isobutane with some photosensitive TMAE admixture.

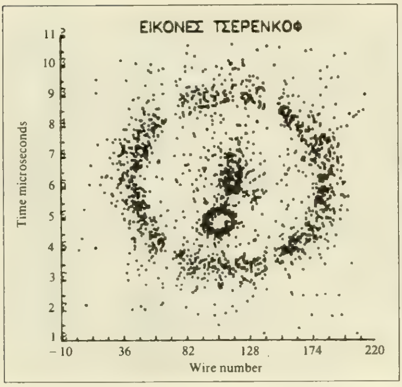
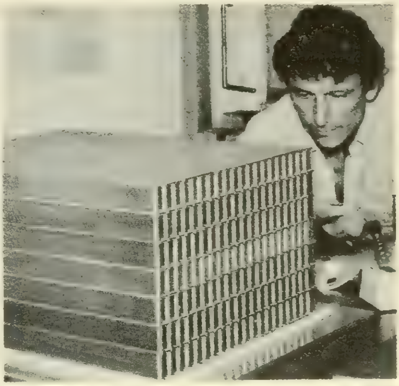


Figure 6 — Two full-size prototypes of sub-units for the DELPHI electromagnetic barrel calorimeter have been built along HPC lines. The converter is made from lead wires glued to both sides of thin fibre-glass strips and folded in a concertina-like fashion. Each wire thus defines a plane through the converter and can be connected to a fixed potential. If this potential is stepped up from wire to wire, the resulting electric field extracts ionization charges from electromagnetic showers or hadrons onto a single-plane multi-wire proportional chamber. (CERN-171.07.84)



area and surface halls were defined and a purchase agreement for these cranes was established between the L3 collaboration and CERN.

The coil of the L3 magnet is a water-cooled, octagonal solenoid of 168 windings which will be operated at a current of 30000 A. The coil is manufactured at CERN from 6 cm thick and 90 cm wide aluminium plates by electron-beam welding. For transport reasons, only half turns are produced as a first step. By the end of 1984, 92 out of a total 336 half-turns were completed.

The magnet coil will be housed in a 90 cm thick iron casing for increased field strength, better homogeneity and reduced stray field. This casing will consist of an assembly of precisely-made pole elements (1100 tons); it will be filled with simple iron bars and plates (5500 tons). The poles incorporate huge swinging doors for access to the muon chamber volume. The first 300 tons of steel, supplied by the Soviet Union, were received by the end of the year. The design of the pole structure was finalized, the strength calculations were reviewed by outside experts, and a manufacturer was selected after world-wide tendering.

Experiment DELPHI

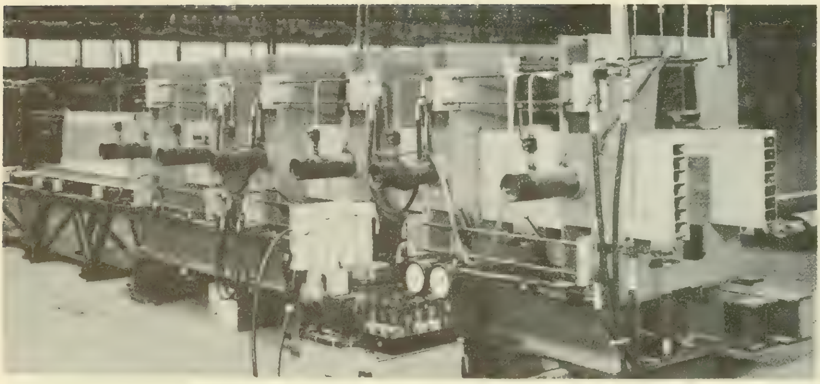
EF Division is working on the 'end-cap' sectors of the Time-Projection Chamber (TPC) which will serve as the DELPHI central detector, on the cylindrical part ('barrel') of the RICH and on the cylindrical part ('barrel') of the electromagnetic calorimeter, a High-density Projection Chamber (HPC). The division is also involved in the cryogenic system for the superconducting magnet.

Work on the TPC embraced beam tests of a half-scale prototype, high-voltage tests of a full-scale plate sector in EF Division, improvement of the efficiency near the edges, further studies of fabrication details, digitizer comparisons, and trigger system design.

Beam tests and simulation studies led to a new circular arrangement for the cathode read-out pads; this geometry provides a spatial resolution similar to that offered by the standard rectilinear geometry, while avoiding cumbersome wire pulse-height corrections. Design details were frozen and production is being prepared.

In the matter of digitizers, a detailed comparison was carried out, in collaboration with CEN Saclay, between CCD ('Charge-Coupled Device') and 8-bit FADC ('Flash Analogue-Digital Converter') systems. CCD systems digitize fast analogue signals by temporarily storing them in an analogue buffer register (the CCD), whence subsequent digital read-out can take place by sampling at reduced speed. The FADC achieves its high speed by carrying out simultaneous comparisons of the signal amplitude with a large number of stored reference signals, thus avoiding the need to store the analogue signal.

Figure 7 — Four metre long hydraulic press for lead-cladding of quadrupole vacuum chambers for the LEP accelerator. (Photo Bleiwerk Goslar)



In collaboration with EP and DD Divisions, a crate controller and a memory module for the new FASTBUS data transmission system were developed. Standard modules were purchased and tested. A 370/E emulator supplied by the Rutherford-Appleton Laboratory (RAL) has been installed and is under evaluation for both on-line and off-line applications.

The prototype of the barrel RICH — containing three full-length drift modules — has produced, in a test beam, first ring images from both liquid and gaseous radiators. Numerous studies were carried out in parallel with the beam tests. For some of these, a full-length test system was constructed and operated successfully with 200 kV drift voltage. Single electrons were produced by a laser beam and detected both on anode wires and cathode strips with full efficiency. Other apparatus has been realized to investigate the flow of the TMAE (tetrakis-dimethylamino-ethylene) vapour used in the Ring Imaging CHerenkov counters, outgassing of materials and reactions with TMAE.

Tests of full-size prototype sub-units of the electromagnetic barrel converter have been carried out in particle beams at DESY and CERN.

Many details of the infrastructure for the experimental area have been studied, and full-scale models constructed for detector and cable layout. Details of the cryogenic system for the solenoid have been defined in collaboration with RAL.

DELPHI contains an unprecedented number of different detector components and therefore gas systems. Standardization and high reliability are mandatory. The design principle for a standard gas system and its microprocessor control has been worked out.

Technical Support for the Construction of the LEP Machine

EF Division participates in various technical activities related to the construction of the LEP machine, for example in the vacuum programme (development of lead shielding techniques for the vacuum chamber and tests of various kinds), the magnet programme (magnetic field measurements), and the geodetic survey programme. A major effort goes into the development of superconducting RF cavities; these may allow the beam energy of LEP to be increased considerably in later phases of the project.

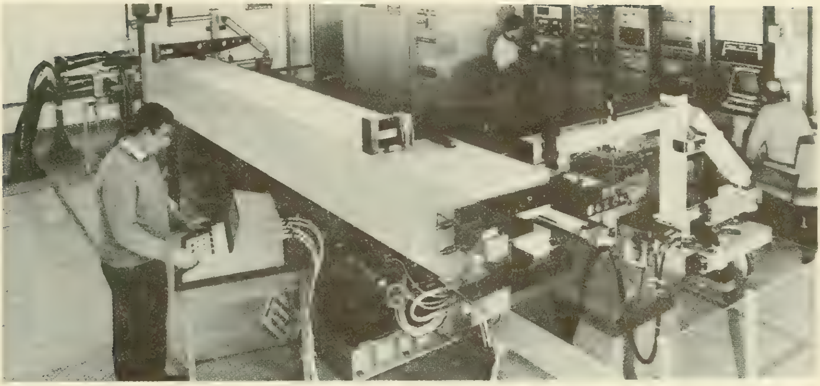
Lead Cladding of LEP Vacuum Chambers

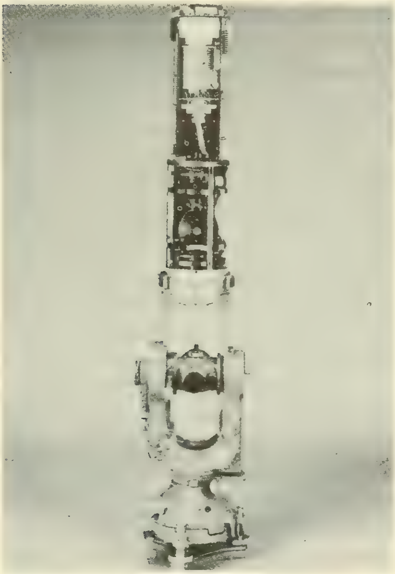
The LEP beam tube is to be encased in lead cladding to absorb the synchrotron radiation emitted by the electron and positron beams.

EF Division has continued to participate in the development of the cladding technology. Based upon the experience gained earlier with a 12 m long pro-

Figure 8 — Automatic LEP Bending Magnet field Mapper. (CERN–408.01.85)

Figure 9 — Gyro-theodolite. In the centre is seen the gyroscope rotor case, with the microprocessor mounted above. (CERN–135.02.85)





totype hydraulic press for dipole chambers, a 4 m long hydraulic press for quadrupole chambers of improved design was constructed. This press is suitable for production work, and a number of quadrupole chambers was satisfactorily clad with it. The successful tenderer for the cladding of all the LEP vacuum chambers decided to purchase it from CERN, for use as a production tool for the lead cladding of all the quadrupole chambers. The same company is now constructing two 12 m long hydraulic presses, using the same basic technology, for the cladding of the dipole chambers.

Field Mapping of LEP Dipole Magnets

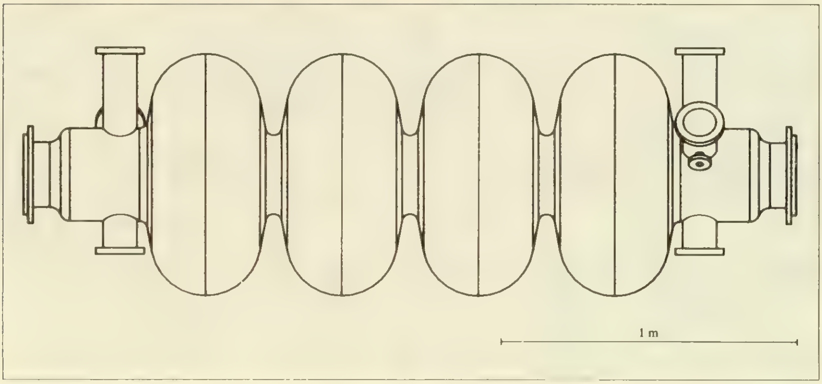
The Division carries out magnetic field measurements as part of general quality control during fabrication of the bending magnets of the LEP accelerator.

The construction of the automatic measuring machine was finished on schedule in July, and the measurement rate reached its full value of 2.5 magnets per week measured with satisfactory precision by November.

Automation of surveying instruments

A mixed EF/LEP team is working on the automation and improvement of several surveying instruments intended for use in constructing and

Figure 10—Four-cell, 350 MHz superconducting cavity for LEP with coupling ports located at beam tubes.



equipping the LEP accelerator tunnels and experimental areas.

DISTINVAR, the first instrument to be fully developed, able to measure distances from 0.4 to 50 m with a resolution of 2 micrometres, is now in series production with private industry. Early production models are entirely satisfactory.

Two prototypes of a gyro-theodolite able to indicate true North with a precision of 10 centesimal seconds of arc (about 16 microradians) in less than a quarter of an hour are performing correctly. The production of a series of instruments by European industry will start shortly.

An instrument for measuring differences in level between two points up to 50 m apart with a precision of 10 micrometres is under development.

The prototype for an autonomous portable data acquisition system is nearing completion.

All the instruments mentioned above use the same ultra-compact microprocessor card which consumes very little power and which can be programmed in BASIC; this card is now produced industrially.

Superconducting RF Accelerating Cavities

The development of superconducting RF accelerating cavities for LEP continued throughout 1984.

A five-cell, 500 MHz cavity previously tested at the PETRA storage ring at DESY, Hamburg, where it reached a field of 2.8 MV/m, was given its first complete chemical polishing, whereupon a field of 5 MV/m with a quality factor ('Q-value') of 10^9 was obtained. This test confirmed that the field limitations previously observed were due only to imperfections in the chemical treatment process and not to specific problems of the multi-cell configuration.

In single-cell 500 MHz cavities manufactured from niobium sheet material of increased thermal conductivity, accelerating fields greater than 9 MV/m (up to 13 MV/m) were repeatedly achieved. The results indicate that the achievable fields scale approximately with the square root of the thermal conductivity.

Efforts were then concentrated on larger cavities, operating at 350 MHz, the LEP frequency. In a single-cell 350 MHz cavity, an accelerating field of 10.3 MV/m was reached, with a Q-value of 4×10^9 at low field and 1.8×10^9 at maximum field.

In view of the beneficial influence of a high thermal conductivity of the wall material on the performance of the cavity, the development of copper cavities sputtered with a thin layer of niobium was actively pursued. In a single-cell 500 MHz cavity, fields up to 10 MV/m were reached without any sign of thermal breakdown. Present studies are concerned with the observed degradation of the Q-value at such high fields.

The design of a cavity for LEP, with all couplers located at the beam tube, has been finalized. Design work on fundamental mode couplers, higher-order

mode couplers and tuning systems is in hand. Horizontal test cryostats for multi-cell cavities with a simplified layout matched to the requirements of LEP are under construction.

Study contracts placed with industry for the development of compact helium refrigerators suitable for installation in an accelerator tunnel have led to very satisfactory results.

A one-week Workshop on RF-Superconductivity was organized in July at CERN by the EF/RF Group.

Cryogenics

Cryogenic activities in EF Division are very widespread, covering operation of cryogenic detectors such as bubble chambers (BEBC and LEBC) and of superconducting detector magnets (Omega, experiments WA75/78 et NA3), cooling of polarized targets, development of cooling systems for LEP detector magnets, studies and technical support for the cooling of superconducting cavities, participation in tests involving cryogenic techniques of all kinds, production and supply of cryogenic fluids and participation in theoretical studies for future superconducting accelerators.

A notable event in 1984 was the commissioning of a new helium compressor. While all compressors hitherto used at CERN are of the reciprocating-piston type, the new machine is a screw compressor with oil injection. Being a rotary machine, it is virtually vibration-free and can be installed without foundations. With suitable measures for sound-proofing, it can even be located inside an experimental hall, a feature very desirable for flexibility in the layout of experiments. The new compressor was in fact installed in the West Experimental Hall, where it operated in the cooling system of the vertex magnet of experiments WA75/78. CERN is principally interested in gaining practical experience concerning long-term reliability of the lubricating oil removal system.

Performance tests with various cold gas turbine nozzles have been carried out on one of the North Area refrigerators, in view of a possible adaptation of this type of plant to the needs of the superconducting magnets of LEP experiments.

Experience with microprocessor-based controls for cryogenic refrigerators was very satisfactory, and existing refrigerators are being modified to make full use of the new technique.

Central helium liquefiers reliquefied about 150000 litres of helium used on the Meyrin site and 160000 litres of helium used on the Prévessin site. About 2.4 million litres of liquid nitrogen and 21000 litres of liquid hydrogen were purchased from outside suppliers and delivered to the users.

Detector Developments

This chapter summarizes a number of current developments in particle detectors, usually undertaken with a specific application in view.

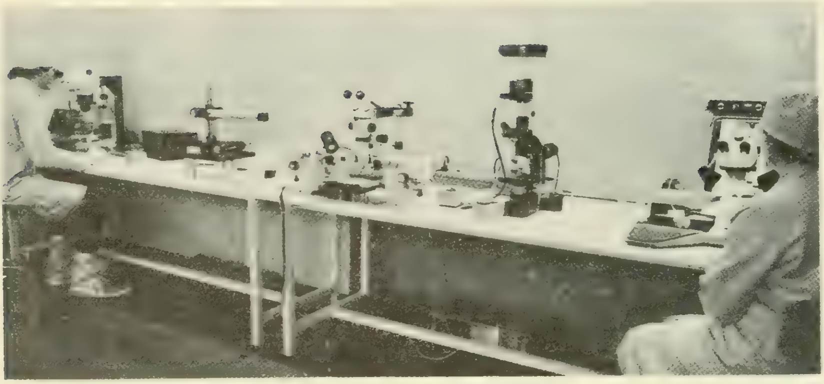
Tests have been carried out on a novel track detector constructed as a matrix of optical fibres made out of scintillating material. Tracks are recognised by noting the scintillation engendered in those fibres which the primary ionizing particle traverses. An opto-electric system intensifies the light signals whereupon the fibres giving rise to signals are identified electronically. Scintillating fibre bundles both in glass, with fibre diameters 10 micrometres, and in polystyrene (fibre diameters 1 mm) have been tried. Once the feasibility of the idea had been demonstrated, effort was concentrated on developing a detector for experiment UA2, using 1 mm polystyrene fibres.

Early tests on detecting the light emitted along a track in a wire chamber developed by EP division have been undertaken, using a sensor consisting of an objective lens, an image intensifier and a light-sensitive CCD.

A micro-vertex system for experiment WA71 in the Omega spectrometer has been completed and successfully used. It consists of five ‘sandwiches’ each with two silicon diode microstrip detectors of 512 active elements (26 mm × 26 mm total active area). In view of the application of silicon detectors in colliding-beam experiments, long-term radiation effects and detector reliability have received particular attention. A preliminary study has shown that an ‘inverted’ structure is more radiation-resistant. In this arrangement, the segmented pattern is made on the ohmic contact side of the silicon wafer, instead of on the rectifying side.

An investigation into the feasibility of a miniaturized detector read-out system using a Charge-Coupled Device (CCD) has been completed in collaboration with industry. A computer-controlled test facility for CCD's is used to measure the performance of prototype devices.

Figure 11 — Assembly of microstrip detectors and microelectronic circuits in a small clean room facility. (CERN–162.01.85)



A thick-film hybridized four-channel adjustable threshold discriminator (MSD3) has been produced in collaboration with DD and SB Divisions. Several thousand of these circuits have been manufactured by industry, principally for experiment NA14.

Film Processing, Scanning, and Measurement

The division was involved in 1984 in the processing, scanning and measurement of all film and most nuclear emulsion from CERN track detectors.

The film-processing service treated about 1 100 km of film from bubble and streamer chambers, and joined with EP Division in processing emulsion from the experiments WA71 and WA75. Tests with plastic track detectors are under way, and early work for experiments EMU01, EMU02 and EMU03 was undertaken.

In 1984 the ERASME/Bessymatic system continued the analysis of film from BEBC, EHS, and the streamer chamber of experiment UA5.

The BEBC experiment WA21 (wide-band neutrino and antineutrino beams; hydrogen in the bubble chamber) had its final run in 1983. It produced a total of 210000 pictures. CERN's share of about 40000 pictures was scanned twice and about 5 000 measurements made on ERASME. For a precise determination of the antineutrino-proton cross-section special scans had to be made seeking single muons originating in the chamber liquid ('one-prongs'). This was achieved with the excellent efficiency of 95% using predictions from the EMI/IPF system to drive the Bessymatic tables to the point on the film where the muon was predicted to leave BEBC.

A total of 120000 pictures taken in 1983 and 1984 by the EHS experiment NA27 with the LEBC bubble chamber was scanned twice in 1984; scanning for this experiment will continue in 1985. The main aim is to select events involving one or two decays of charmed particles and 4500 candidates were found and passed on to ERASME for high-precision measurements. Event-finding during scanning is helped by predictions from beam monitors which are fed through to the Bessymatic tables.

The analysis of film taken by experiment UA5 in 1982 was completed.

The improvements to the film/hologram scanning and measuring machine HOLMES were completed at the beginning of the year yielding better reliability, flexibility and speed. HOLMES went on to complete the analysis of some 9000 holograms from the bubble chamber HOBC taken in 1982 for experiment NA25.

Data Handling Division

An example of a mixture of text, mathematical formulae, and figures obtained using the IBM document composition program ICEF and the APA6670 laser printer.

Data Handling Division

Introduction

The computing requirements for the LEP era are such that CERN's computing facilities need to be greatly extended. Based on studies which took place during 1982 and in early 1983, an overall plan was established in spring of this year, which covered the necessary increase in centralized computing power as well as the needs for data communications and for on-line computing. This year's efforts were concentrated on realizing the first steps towards a substantial increase of computing power in the Computer Centre. After successful negotiations with mainframe manufacturers, in October the Finance Committee approved the purchase of a Siemens 7890-S. This dual processor machine has four times the capacity of the present 7880 and will replace it early in 1985. An agreement of principle was also reached for a similar upgrading of the IBM machine.

Following the installation of a CYBER 170/835 and a 170/875, the CDC 7600 was definitively powered-off in the summer, after 12½ years of faithful service. Its functions are now completely taken over by the 875, which is delivering double the 7600 capacity on a regular basis.

The IBM/Siemens systems continued to perform extremely well during 1984. The reliability of the Siemens 7880 has been excellent, and not a single hardware failure occurred in the machine during the year. A new record was achieved for the number of jobs (34000 jobs in one week).

Preparations for the introduction of an interactive user service on the IBM/Siemens complex required a major effort this year. The VM/CMS operating system was introduced on an experimental basis for selected users. The services of VM/CMS will be made generally available in progressive stages during 1985.

In the data communications domain, a steady increase of demands and of services has been observed. CERNET connections now exceed 100; more than 100 new terminals were installed, and 10000 calls per month are being made on the Swiss public network, to access CERN's computers via the EXternal Terminal Access SErvice (EXTASE). A first ETHERNET Local Area Network was set up in the Division and a small on-site X-25 network was established. The General Internetwork for File Transfer (GIFT) project is well under way. A main node for the European Academic and Research Network (EARN) was installed; EARN will eventually link more than 100 European institutes together and to the American network BITNET.

The PRIAM VAX, running the UNIX operating system, went into full production for microprocessor support. The complete range of cross-software for the Motorola 68000 processor is available on this machine, including compilers for FORTRAN, Modula 2, Pascal, and C, and the M68MIL assembler. The symbolic debugging monitor MoniCa is installed on a considerable number of different hardware configurations.

A new generation of interactive, relational database management systems was introduced a few years ago with the installation of ORACLE. This type of system is now seen to have fulfilled its promise of allowing users, who may have little or no experience in computing, to develop applications themselves.

Personal Work Stations of the Apollo type are becoming more widely used, and this year's efforts were concentrated on their integration into the CERN programming environment. Different projects for their integration into the physics environment have been started in collaboration with physicists from CERN and outside institutes.

In the field of the off-line programming support, the expected shift of effort from SPS experiments to LEP experiments took place. The accent on the type of support given has also shifted over the recent years, from mainly writing and testing algorithms (track finding, track fitting, etc.) to more computer-oriented aspects such as the design of adaptable programs, the development of general programs for event simulation and presentation, and the development of general tools (especially for interactive use). The algorithms themselves are written more and more by the physicists taking part in an experiment. These developments in fact make good use of the experience of the Division's professionals.

The Division continued to be active in the application of graphics to help solve physics problems. PIONS, developed in the Division, will evolve into the interactive, real-time 3D graphics system for the LEP collaborations. Clearly, the success of this type of graphics in the UA1 context has had a strong impact on LEP physicists. On the other hand, the introduction of a full implementation of the ISO Graphics Kernel Standard (GKS) has started, which will allow us to profit from the availability of a large spectrum of hardware and software.

For on-line computing, the emphasis has been on support for 32-bit machines, and the ND-100 is now

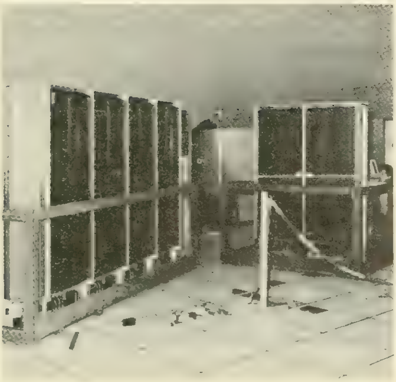


Figure 1—A departure ... (the CDC 7600 in its crate, just prior to leaving the site). (CERN-353.12.84)

the only 16-bit computer where software development is not yet entirely frozen.

The needs of the LEP experiments for on-line software in the production environment are at present under study.

CAMAC-to-FASTBUS interfaces have become available, supported by a standard software package; also, a number of VME-based test systems are in use, mainly for the development of FASTBUS modules in the EP Division.

Two prototypes of the 3081/E, the new emulator of the IBM 3081, were constructed at SLAC and at CERN; they were debugged simultaneously and put into operation. The construction of a small production series of the machine has started. A pilot project to build an emulator farm, with five machines for off-line processing, has started. This project should prove that part of the additional computing power for the LEP era can be obtained using cheap emulators.

Central Computing Services

CDC Services

After 12½ years of service, in June the CDC 7600 reached the end of its life at CERN, having achieved an availability of 96.4% and an MTBI of 38.7 hours since the beginning of the year.

Initially used as front-ends to the CDC 7600, the CYBER 875/835 twin system took over the whole CDC production as of this summer, after user conversion to NOS/BE had been successfully completed.

Availability of the 875 has been at 96.6% for the year, with an MTBI of 50.7 hours. On the average, the machine processed 6328 jobs per week for 199.4 hours of user CPU (which corresponds to 712 IBM 168 equivalents), with records over the period of 10761 jobs and 277.7 CPU hours (= 991 IBM 168 equivalent hours) in a week. The reliability of the new systems has been disappointing, but corrective measures taken by CDC should bring about an improvement in 1985.

For the system software, the main emphasis was on the implementation of required features (file table expansion, multi-file tape staging, charging, SPY, GEMINI), and on trouble-shooting. Work has also started on the conversion to INTERCOM 5 in order to replace the old CERN multiplexers for INTERCOM with standard CDC hardware. The Program Enquiry Office made a major effort in user conversion, giving seminars, producing a users' guide and providing individual help to many groups.

Migration of the full CERN Program Library from the CDC 7600 to the NOS/BE operating system on the CYBER 875 was completed. The appropriate short and long write-ups were modified. Programs were written or modified for the transfer of accounting functions from the CDC 7600 Scope 2.0 to the CYBER 875/835 NOS/BE systems.

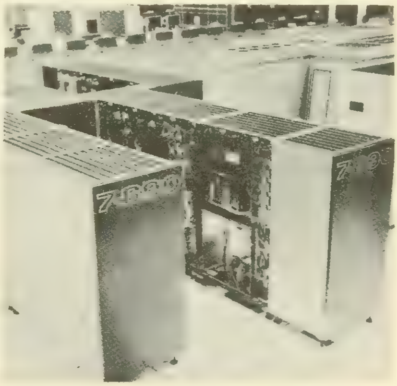


Figure 2—... and an arrival. The Siemens 7890 replaced the Siemens 7880 a few days before Christmas 1984. (CERN-341.12.84)

IBM and Siemens Services

The performance of the IBM 3081 system during this period has been very good, with an availability of 99.4% and an MTBI of 202.4 hours. These figures are very similar to those of the corresponding period last year, but unfortunately more unscheduled hardware incidents occurred.

The performance of the Siemens 7880 system has again been excellent, with an availability of 99.7%, an MTBI of 214 hours, and no hardware failures.

The major upgrades have been on the IBM 3081, with the installation of an additional 8 Mbytes of memory and 8 channels in order to provide a configuration which is better balanced to cope with the daytime load.

It should be recorded that whilst tape performance has been generally good throughout the year, the first signs of user unrest are appearing as the work load increases.

The average weekly work load figures show a slight increase in the number of CPU hours achieved (656.6 IBM 168 equivalent hours) and a big increase in the number of jobs run (30054 jobs). The record levels this year are 794.9 CPU hours and 34252 jobs in one week.

On the software side the biggest achievement was the introduction of a new version of JES2 in August. About 14000 lines of local modifications had to be adapted from the old release of JES2, which had been running since February 1980. The introduction went quite smoothly, and the few problems that appeared were quickly resolved. The main features of the new version are the possibility to use high-capacity disks (600 Mbytes) for spooling, and the definition of up to 1000 nodes in the Network. The latter feature will soon be exploited by the European Academic Research Network, which will link hundreds of nodes in Europe and the USA to CERN.

Another area of activity has been the continued support of the MVS/WYLBUR service where there has been a tremendous growth in the number of files created. In fact today, 34 000 more files are supported than was the case 12 months ago, corresponding to an increase of more than 30%. This phenomenon creates a high pressure around space administration where audits and catalogues increase at an alarming rate.

WYLBUR and MILTEN have been more or less stabilized, and effort has instead been put into the preparation of the VM service which is now targeted to begin next year.

VAX Services

A further three VAXes (all 11/750's) were installed during 1984. One of these was to provide extra computing power for the LEP data-base project as an interim solution, one for SB Division for office automation, and one for the GIFT project. The LEP data base and CAD/CAM 11/780's are scheduled to be upgraded into 11/785's before the end of the year. The planning and preparation for the installation of three VAX 8600's in 1985 has been a major activity during this year.

Overall, the machines have performed well, with availability above 99%. An area of weakness continues to be the peripheral performance. Steps are being taken to reduce the dependency on poorly performing devices.

Remote Access to Central Computers

Remote Batch Service

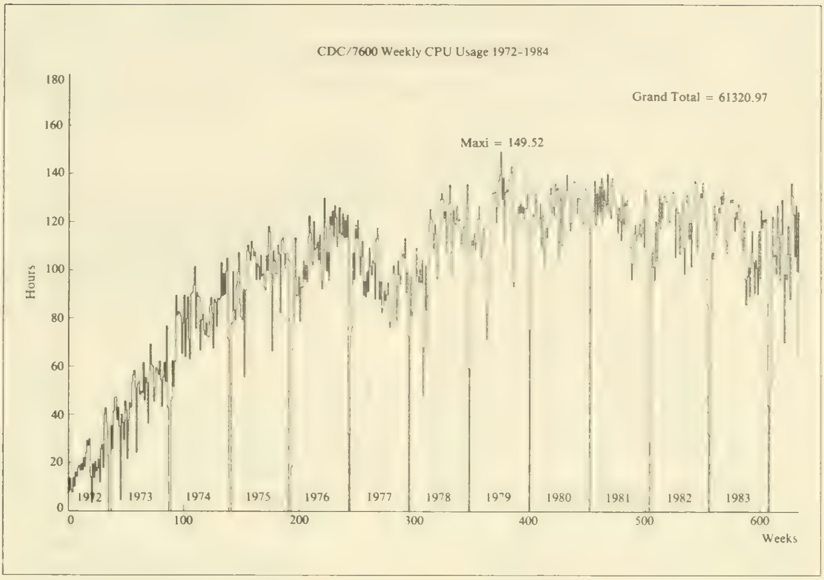
The CTL remote batch stations have continued to work smoothly throughout the year. The two stations in Building 13 were replaced by a DIGITAL 1200 lpm printer connected to a local VAX. The ISR remote station was replaced by an IBM 6670 laser printer.

INDEX

INDEX now provides 1300 terminals with connections to 1000 computer ports. In the last 12 months the total connect time was 760000 hours. The work carried out during these 12 months comprises 294 INDEX 'terminal line' installations and moves, 117 INDEX 'host interface' connections, 152 terminal deliveries and exchanges. In addition, 29 synchronous and special lines and 19 Modems and PAD (Packet Assembler/Disassembler) connections were installed. The old gateway mini-PACX (for external and X-25 traffic) became saturated and was replaced by a larger unit. A planning for the expansion and upgrading of the 'central' INDEX system has been established and a first hardware order made.

Two Time Division Multiplexers have been commissioned, offering: 22 cross-connect channels between INDEX-4 (EF/EP) and the Computer Centre, and 12 channels via the G700 data link between INDEX-3 (SPS) and the Computer Centre.

Figure 3 — Weekly central processor use of the Control Data 7600 during its 12½ years of life at CERN.



Terminals

The terminal pool now contains 1657 units: 234 graphics terminals, 1191 alphanumeric terminals and 232 printers/printing terminals. In addition to this, the first-line maintenance of 20 Matra work stations is carried out regularly.

User Support Services

Program Enquiry Office

On the MVS/WYLBUR system, the emphasis has been on maintenance work, notably in the areas of WYLBUR Help and Tools, MSS (Massive Storage System) support, Monte Carlo physics programs, graphics, and microfiches.

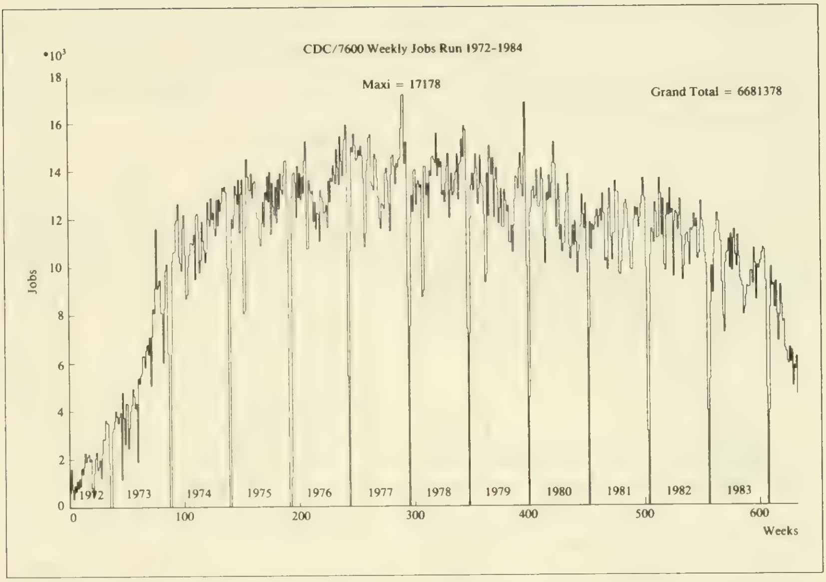
Most development work has been in the field of the VM/CMS system. Courses have been organized and attended, and the foundation of a general user service has been established. Although this has been mainly a learning phase, many utilities have been written, installed, and evaluated.

In the area of text processing, CERNPAPER was put into production as the recommended fully supported SCRIPT macro system, and development has started to support the production of more complex documents using CERNPAPER and the APA6670 laser printer. SCRIPT support was provided for the new phototypesetter of the DOC Department.

Program Library

The public presentation of the restructured CERN libraries was completed with the creation of sets of new procedures on IBM and CDC and the deletion of the old library files. Migration towards FORTRAN-77 continued with the formal freezing of

Figure 4 — Number of jobs run per week on the CDC 7600.



the FORTRAN-4 version of the CERN Program Library. A new version of the Siemens FORTRAN-77 compiler and library were installed on IBM under MVS, and a first version was installed under VM/CMS on IBM. An evaluation of the IBM FORTRAN-77 compiler interactive debugging product was performed in collaboration with IBM. The production version of KAPACK, a FORTRAN callable keyword access package, was released and is now being widely used.

The Program Library documentation access under WYLBUR was improved with the addition of an entry point search mechanism. A first version of on-line documentation access under the IBM VM/CMS operating system has been prepared. The new version of the manual, printed on the XEROX 8700, permits a paper saving of 70% of the previous version.

Work has started on the implementation of the CERN library under the IBM VM/CMS operating system. It has been decided to support only FORTRAN-77 in this system.

Mathematical Consultancy

Work in support of lattice gauge calculations has continued. New algorithms have been explored in order to improve efficiency of computation. The scope of existing programs for the CDC and CRAY computers has been broadened to confront a larger variety of problems. A new method of I/O buffering has been developed to cope with larger lattices. Monte Carlo calculations have been performed on the CYBER 875 computer to obtain gauge fields for lattices of some 200000 nodes.

Work continued on electrostatic fields and induced charges on strips in wire chambers. The analysis and programming of the electrostatic field of doubly periodic infinite arrays was completed for the

thin-wire approximation. Program testing began for the thick-wire case, based on the use of a doubly periodic multipole expansion for the potential. Usable explicit series expressions were found for certain Fourier transforms needed in the numerical solution of the problem of induced charges on strips.

A further investigation of the Landau and Vavilov distributions has been made together with a new version of the Library Program for the Landau distribution. This work required the installation and testing of a new version of REDUCE.

In connection with the CERN technology study, about 35 firms were interviewed, the statistical analysis of the data was finished, and the final report has now been published (CERN 84–14).

Accounting

During the past 12 months about 800 new IBM and 280 new CDC accounts have been opened. The EXternal Terminal Access SErvice (EXTASE) has about 80 users, from whom must be recuperated the SF 40000 required to pay the PTT bill.

A major effort has been put into preparations for the introduction of the new VM/CMS service.

Tapes

Clearing-up of the tape vault is continuing, and the ancient data base has been replaced by a new MVS-based system. At last, systematic garbage collection has been authorized and has started among the numbered CERN tapes.

Data Communication Networks

On-Site Networks

CERNET

CERNET has continued to work reliably with an average availability of 99.45%. One new Modcomp Classic node has been added in the West Hall Area.

The support for the communications subnetwork of the CERNET packet-switching network is now mainly a service activity. Some 25 new connections have been made to CERNET, whilst about 15 have been suppressed, bringing the total number of user connections to well over 100. The overall usage is constantly increasing, especially in the area of the virtual terminal service into WYLBUR: current figures are around 4000 sessions per week. During busy periods, lasting hours or days, the traffic on CERNET averages 50 kbytes/s and more.

The current node software allows for almost all known future connections (definite or provisional), including those for interconnecting various ETHERNETs. Modifications to this basic configuration will become necessary as part of the introduction of VM/CMS on the IBM and Siemens mainframes next year.

The use of G700 for data transmission over CERNET has proved to be working well; currently two speeds have been implemented (2048 kbits/s and 8448 kbits/s). A CERNET link running at the speed of 8448 kbits/s has now been operational for about one year between the Computer Centre and the North Area.

Local Area Networks

A prototype ETHERNET network has been installed in Buildings 31 and 513, with the intention of gaining experience with both the hardware and the software. This network now has more than ten computers attached, almost all of different types, and is used as a real service by many of them. Two terminal concentrators, of the type used at SLAC, are on loan, and are providing a test service to several programmers.

The Division has taken an active part in the installation of various ETHERNETs around the CERN site, and is acting as a central consultation and coordination body. All CERN ETHERNET installations are monitored and the results are reported to a coordination committee known as EPIC (ETHERNET Pilot Installation at CERN).

As a part of the development work aimed at providing a service to interconnect Local Area Networks (LANs) via a CERN-wide backbone network, a Flexible Reconfigurable Internetwork GATEway (FRIGATE) has been constructed. The first service foreseen for this unit was the interconnection of different ETHERNET segments via CERNET. This has now been achieved, providing DECNET connections over two physically different ETHERNETs in Building 2 and Buildings 31/513.

Using the microprocessor support system PRIAM, software was developed to run under the RMS68K operating system. Various other software packages are being written for the FRIGATE hardware in order to offer services to any of the computers connected on ETHERNET. Servers for assisting with file or terminal access to other computers around CERN are being developed. Studies are being carried out to determine how to use another variant of the FRIGATE unit to support additional services such as X-25 connections. Investigations into the availability of LAN technologies other than ETHERNET, with particular reference to the ISO DP8802 draft standards, are beginning.

Higher levels of data communications software are also under study. In the long term, ISO standards will be used. For the interim period, and in order to become familiar with these emerging standards, two *ad hoc* working groups have issued their recommendations. One, called the Datagram Definition Group (DG2), is concerned with a site-wide internetwork datagram format. The second, called the Remote Procedure Call Club (RPClub), treated the options for remote procedure call protocols. Both reports have been widely circulated.

X-25 Service for On-Site Computers

Three X-25 switches from CAMTEC have been installed to form the kernel of an on-site X-25 network. After seven X-25 connections were moved from the RAL GEC switch to the CERN X-25 network, 16 user machines were connected. Straightforward X-25 access to TELEPAC, JANET, and Saclay is available. Interworking with EXTASE, for terminal access only, is also provided.

Miscellaneous

The Division assisted SB in the choice and installation of terminals, printers, and the related connections for the various building sites for LEP. As a result, three voice grade Modem links, one pair of statistical multiplexers, and two baseband Modem links were installed to permit access to the 'All-in-1' VAX in Building 513.

Laboratory tests to evaluate Data-Over-Voice (DOV) are being carried out and a field test proposal is in preparation.

Off-Site Communications

EXTASE Service

The EXTASE service (two-way terminal access to public X-25 networks) has reached a level of

- 10 000 communications per month,
- 1600 hours of connections per month,
- 150 Mbytes exchanged per month,
- 300 outside institutes or computers communicating with CERN.

An off-line program for analysing the X-25 traffic, based on the SAS (Statistical Analysis Systems) product, has been developed. With this it has been possible to improve our facilities to understand this traffic. The accounting system set up for EXTASE has been extended to handle calls originating from the CERN X-25 network computers. After a detailed study of the various possibilities, it has been decided to install, evaluate, and run the COMPRO product on the 3705 as the only short-term solution for improving external access to WYLBUR and VM/CMS. The Series 1 approach does not offer short-term solutions.

EARN

The CERN node of the European Academic Research Network (EARN) has been installed and now has direct leased lines operational to the Universities of Berne, Zurich, and Geneva. With the opening up of the first international link in October 1984, to GSI Darmstadt, EARN entered its experimental operation phase for communications between Switzerland and Germany. The traffic has been growing impressively. A software gateway between the WYLBUR Electronic Mail Facility and EARN has been developed and installed.

The GIFT Project

The VAX 11-750 was delivered in October 1984. The CERNET and DECNET parts of GIFT are ready and integrated for the access to the CERN IBM. An experimental service is due to start in January 1985 with CERNET, DECNET, and JANET protocols. UNINETT has announced some delay in the provision of their part of the GIFT software.

Electronic Mail

The COMICS (COmputer-based Message systems InterConnect Strategy) interdivisional study group was set up to study this question, in the first place for CERN and then in the wider framework of the high-energy physics community. An interim report has been written and the final report was completed by the end of the year. The main results so far are the emergence of the CCITT X400-MHS standard as the recommended medium, and the elaboration of an intermediate technical solution for interconnecting existing mail systems. The solution is based on a central multi-protocol gateway machine, the principle of which is close to the concept used for GIFT.

A project which aims at providing a gateway between the CERN TELEX service and the central CERN electronic mail facility has been elaborated jointly with the PE and DG Departments.

European Networking Activities

A considerable effort was made to support the EEC-sponsored action for the harmonization of communication protocols (in the context of ESPRIT). In particular, CERN organized two of the meetings, which were on Terminal Protocols (Triple X). Staff participated actively in the ECFA Working Sub-Group 5 activities. A leading role was played in the setting up of a proposal for an ESPRIT project on distributed directory services and other electronic mail aspects.

Specialized Computing Services

LEP Services

The activities concerning CAD/CAM for the LEP construction and other mechanics applications are reported in the LEP Division's contribution. The Data Handling Division continues to be heavily involved in this project. Also, the services provided by DD and related to the use of the ORACLE Data-Base Management System for the LEP construction and for some SPS applications are reported by the LEP Division. The DEC electronic mail system 'All-in-1' which links the SB buildings to the various work sites around the LEP ring during the construction phase, and which was initially operated on the LEP data base VAX 11/780, moved to its own VAX 11/750 in June.

Microprocessor Support

The export trade in microprocessor cross-software has flourished this year: out of a total of 47 requests treated, the majority (30 requests) has been for Motorola 68000 support software running under VAX VMS.

FORTRAN and C cross-compilers and run-time libraries for the MC68000 have been obtained from Associated Computer Experts BV, Amsterdam, and made available on VAX computers running UNIX and VMS.

The implementation of a dual head, single tail, compiler for translating Modula-2 and Pascal into 68000 code has been completed. This compiler allows programs written in one of the two languages to benefit from improvements to facilities for the other, thus reducing the effort required to support the two languages.

MoniCa, a monitor with facilities for interactive symbolic debugging using the symbol tables produced by the 68000 Modula-2 and Pascal compilers and by the M68MIL assembler, now runs in several 68000 systems, both at CERN and elsewhere. MoniCa's input/output system has been adapted to run under RMS68K, Motorola's real-time kernel.

Subroutine packages have been written for arithmetic operations on IEEE single-precision floating-point numbers, and for approximate arithmetic on IEEE double-precision numbers.

Personal Work Stations

During this year the work of the project has been concentrated on the integration of Apollo work stations into the CERN environment of FORTRAN, graphics, communications, and system management. The two Apollo work stations owned by DD Division were joined early in the year by a third machine, a small DN300, which was installed in UA1 and connected by the Apollo Domain network to the machines in DD. In spite of the large distance of 1.2 km between the machines, the network functioned perfectly. The collaboration with UA1 physicists has proved valuable in giving us good input on how we should integrate

work stations in the physics environment. A fast communication link between Apollos and the main IBM machines was established by accessing a CERNET server via ETHERNET. The CERNET server, MECGATE, handles all the complexity of accessing IBM, CDC, and VAX computers over CERNET. The facilities offered include file transfer, central printing, listing of IBM catalogues and directories, job submission, and job retrieval.

As VAX computers are also extensively used for physics, connections to Apollo have been made via MECGATE for file transfer, and also using commercial products such as ETHERNET and the ARPANET protocols (TCP-IP). The ARPANET protocols support remote log-in as well as file transfer.

UNIX mail has been implemented using the AUX UNIX interface on Apollo. This incorporates the Apollo into a larger CERN scheme and gives it access to outside laboratories.

The Graphics Kernel Standard (GKS) is a library of two-dimensional graphics routines that are implemented on different hosts; it supports a wide range of graphical input and output devices. An implementation known as Minimal GKS, which offers GKS-level mb functionality, has been developed on the Apollo for use on smaller systems.

Many of the physics packages such as HBOOK, HTV, etc., are now in use on the Apollo. A Graphics User Interface (GUI) enables users to modify their output by adding graphics and text. The output may then be printed on the Versatek plotter which was installed earlier this year.

PIONS, a three-dimensional graphics system, has now been ported to the Apollo. The CERN library is also being ported to the Apollo and will be officially supported. In the meantime, experience has been gained by adapting a selection of routines required by the user community. The management of distributed computing facilities is under study. This includes management of network connections, introduction of new users, installation of new hardware and software versions, libraries, problem logging, maintenance, disk space control, documentation, contracts, program enquiry functions, etc. A recurring theme throughout these studies is to balance the advantages and disadvantages of central support versus users taking local responsibility for their system.

There is a continual evaluation of new personal work stations. There has been experience in using the PERQ-2, the SUN, the Symbolics 3600, the CADMUS, and the Diser Modula. Presentations have been given by a few other companies (e.g. DEC and Masscomp).

The PERQ-2 work stations have been used to implement a graphics animation package and a terminal emulator. The project keeps in close contact with ICL and the SERC regarding future developments of PERQs, and these machines will be used to demonstrate the integration of UNIX systems using the Newcastle Connection.

Hewlett-Packard has lent us an HP-9000, which has been used extensively by two visiting physics groups. The Digital Equipment Corporation has lent us a VAX-compatible VS1 work station. CERN plans to rent a Symbolics 3600 to perform algebra manipulations. The SUN-1 was demonstrated using ARPANET protocols (TCP-IP) in order to communicate with the UNIX VAX over ETHERNET.

A collaboration with IBM to study the use of the IBM-PC in the scientific and technical environment found at CERN came to an end. The results showed some interesting individual developments and, since the end of the collaboration, many IBM-PCs have been purchased by CERN.

UNIX

The start of the year saw the introduction of the UNIX service on the PRIAM VAX, based on the Berkeley 4.2 software distribution. During this start-up phase, the connection of the VAX to CERNET was completed, and services for file and mail transfer were offered to users. A CERNET file manager was written to satisfy the needs of users wanting to down-load programs generated on the PRIAM VAX into target microprocessor systems by CERNET file transfer.

The community of UNIX users has grown steadily since the initiation of the service, with currently over 170 registered users. The hardware configuration of the system was enhanced in June with the addition of two large Winchester disk drives, each of 450 Mbytes, and a further 16 terminal ports. In addition, several new software packages have been made available to users, such as UNIX news (a bulletin-board system) and the Notesfile system for storage and retrieval of documents. Furthermore, connections to other mail systems have been implemented (MLNET and EAN, with plans to connect to EARN quite soon).

In the networking area, the connection to the European UNIX User's network has been upgraded to

use the public X-25 service, and considerable experience has been gained in the use of the various protocols over ETHERNET.

Relational Data-Base Management Systems

The Data-Base Management Systems services include the testing and introduction of new versions of the ORACLE system, and development and management of general utility functions. ORACLE is now being installed on a number of VAX computers, and it is planned that an interactive data-base service be provided on the IBM central computers, using the query language SQL on which ORACLE is based, either through ORACLE or IBM's SQL/DS, both of which are being evaluated.

In line with the recommendations of the ECFA Working Sub-Group 11 on Data Bases and Bookkeeping for HEP Experiments, a bookkeeping pilot project using ORACLE was started with the ALEPH Collaboration on one of their VAX 11/750 computers.

The CERN Experiments File, which is maintained under INFOL, has been modified to allow for the large number of physicists and institutes participating in the LEP experiments.

Data Handling

Off-Line Processing

General Development

Collaboration with programmers and physicists from EP Division has been very successful, the most outstanding examples being the programs ZEBRA and GEANT3.

The GEANT3 program, initially developed in the context of the OPAL Collaboration, is now being used by several other experiments (ALEPH, L3, CHARM II, and NA34 at CERN; SLD at SLAC; two experiments at Fermilab; two experiments at HERA). The European Space Agency (ESA) intends to use this program for the simulation of cosmic rays crossing satellites. Many physicists, in particular from L3, are developing code for electromagnetic and hadronic cascades.

A Graphics User Interface (GUI) has been developed on the Apollo, and the first part of this project is now in the completion phase. GUI is the combination between a 'POP menu' package and a graphics and text editor. It uses most of the graphics capabilities available on a bit-map display.

After the decision to discontinue the development of GEM, the ZEBRA data-structure management system was proposed in February by members of the EP and DD Divisions. The implementation of the memory management package started in April and a first release was available in September. This package as well as the debug package developed by DD is now under evaluation.

To get acquainted with VM/CMS and to test the interactive debugger of IBM on that system, an early version of the ZEBRA debug processor was developed and debugged on VM/CMS and the IBM VS compiler version 3. Some bugs were found and reported to IBM.

Graphics

A considerable part of the work load for the Graphics Section consists in giving support to the MERLIN facility for UA1/UA2; this includes operational support, system support and programming development. In addition, support and advice is given to a number of outside laboratories in the UA1 Collaboration which are running MERLIN-type installations. The number of such installations has increased by a factor of 4 in 12 months.

At the request of UA1, effort has been devoted to porting PIONS to Apollo for use by Saclay and NIKHEF (Amsterdam) in Apollo/Megatek configurations. This work will be completed when the necessary hardware becomes available. The PIONS kernel is operational on Apollo, and a provisional driver has been written to make use of the Apollo work station's inherent graphics capabilities. The PIONS precompiler was adapted to make it run under VM/CMS.

Working group meetings with the LEP collaborations were held in order to define their graphics needs. The ALEPH and DELPHI Collaborations have started using PIONS on both Megatek and other graphics displays, and PIONS is also used in production at DESY by the TASSO experiment.

A basic-level GKS implementation (MGKS), adhering to the ANSI-defined-level mb, was started using FORTRAN-77 as the implementation language. This version of GKS is intended for use by small applications, primarily on minicomputers and micros. It is

currently running on VAX and Apollo. Porting to MC68000 is foreseen. A number of GKS work stations are supported, including the Tektronix 40xx series, Versatec plotters, and Hewlett-Packard plotters. In addition, MGKS supports the GKS Metafile. The GKS Metafile will allow any application running on a machine other than the central IBM service, to create, store, and ship graphics data to the Computer Centre via CERNET.

In order to obtain a full GKS implementation for CERN (and outside laboratories), a number of software houses were contacted to invite offers for a GKS source licence. It was decided to select the PLOT-10/GKS implementation by Tektronix, which was offered at a very substantial discount. By January 1985 it will be available on IBM VM/CMS and VAX VMS. The GKS service will gradually be introduced on IBM MVS, IBM-VM CMS, VAX VMS, and ND-500 between early 1985 and mid 1985.

On-Line Processing

Pool Activities

The policy decision to shift support from 16-bit computers to 32-bit systems had consequences for the On-Line Computer Pool. In fact, about 10 16-bit computers were withdrawn from the Pool after the shutdown of the ISR and the end of several fixed-target experiments, whilst the LEP experiments now have a total of nine VAX computers supported on the site.

A considerable fraction of the On-Line Computer Pool support activity is devoted to visiting teams that have their own computers on-site and even off-site. Support for about 80 CAMAC System Crates represents a heavy load. The FASTBUS Interface CFI was added to the Pool as standard equipment and a corresponding support service was set up. OMNET could be further reduced but has still to be supported, mainly for the European Muon Collaboration (EMC).

Many Pool configurations underwent modifications or had to be reconfigured in order to standardize equipment or to save on maintenance costs. There was a big demand for upgrading existing on-line computer systems. At the EMC and NA10, the magnetic tape subsystems could be improved without making any purchases. The three UA Experiment Improvement Programmes also triggered requests for increased on-line computing power: with minimum purchasing, two Pool systems could be upgraded and reallocated to UA5 and UA1, but for UA2 an additional VAX had to be bought.

DEC Support

Substantial improvements have been made to the VAX data-acquisition system. An upgrading programme was agreed upon with the LEP collaborations to cover their immediate needs in the test beams; most of this was completed for the 1984 fixed-target period. The system can now deal with larger events, and has more flexible CAMAC list facilities (permitting dialogue with intelligent front-end processors and with the CFI FASTBUS interface). The efficiency of the system has been improved in several areas, including a faster communication mechanism between data-acquisition and monitoring programs. Data recording on disk is being implemented. Other improvements have been made, in particular for the PILOT program which organizes the monitoring programs. Effort has gone into the methods for installing, distributing, and updating the software.

Participation in networking activities has continued in several areas, e.g. in the EPIC (ETHERNET Pilot Installation at CERN) project and in the development of software to run CERNET over ETHERNET for the FRIGATE program. Support for users of the UK JANET network software on site, and for users of DECNET, was provided. Participation in the COMICS electronic mail study and help in evaluating the JANET software for connection to EARN were also a part of these activities.

The VAX-ELN operating system, which has been installed on a microVAX, is being evaluated. The work necessary to reprogram those parts of the software which use the VAX in PDP-compatibility mode has started. In this context the Pascal version of the WYLBUR Bridge has been brought up on the VAX.

Support for experiments has been maintained at a high level. Use of the VAX data-acquisition system has continued to grow as more VAXes are installed. The LEP collaborations now have 9 VAXes on site, a further 4 run the data-acquisition software in other experiments, and more are on order. Use of the data-acquisition system by groups in their home institutes has also grown: there are now at least 12 such installations, mainly in the LEP collaborations. With the closing down of the ISR and of some SPS experiments, the number of PDP-11s in use has been somewhat reduced. Over 20 still run the standard data-

acquisition system however, and some software and support is provided for many more.

The PDP data-acquisition software has had a final upgrade and is now considered as frozen.

NORD Support

All ND-500 and the majority of the ND-100 systems were upgraded to the I-version of SINTRAN, implying a non-trivial change to new memory management hardware and software, and consequently to the data-acquisition system (DAS). The Division has received a small ND-500 system for software developments.

For DAS a source-file data base was developed to ease software maintenance, version control, and distribution. A first version of DAS routines for the ND-500 was developed and installed at UA6. A portable, FORTRAN-77-based version of the DAS kernel, called MicroDAS, has been produced and successfully tested on ND-100, VAX, Apollo, and MC68000. The VAX version is used for data-taking with FASTBUS in experiment NA31.

SINTRAN work included a joint development with Norsk Data to use, for the first time, the new memory management hardware providing for 16 page index tables (PITs) to overcome address space limitations. Discussions with Norsk Data's development department intensified after they had announced major changes in their SINTRAN planning in February. The J-release of SINTRAN will arrive at CERN with the development ND-500, including hardware and software for Norsk Data's new serial control-bus to be used in the ND-500 FASTBUS interface.

A file manager for CERNET was installed on top of the new Pascal-written portable transport manager. ETHERNET tests with prototype interfaces started in the spring. New tests with interfaces from a preproduction series and a FORTRAN-callable datagram package have just begun. Preparations for the installation of the CERNET protocol above ETHERNET datagrams are being made.

CERN's standard FASTBUS software was installed on the ND-100, and the Division participated in the development of a 'direct' FASTBUS interface to the ND-500, allowing 32-bit parallel transfers at a speed exceeding 10 Mbytes/s.

With the help of the French Tore Supra project, a portable command processor was developed, the FORTRAN-77-written MiniZCEDEX package, which is now running on ND-100, ND-500, VAX, and MC68000 at CERN.

General On-Line Development

The first official release of the Portable Interactive Language System (PILS) V.1.0 was introduced in spring and installed under VAX VMS, VAX UNIX, VALET, and ND-100/SIII. The package includes FASTBUS and CAMAC standard libraries. A prerelease of PILS V.2.0 is under test. It includes a code generator for the VAX, giving significant performance improvements.

Nine 'VALET', VME bus-based, small test systems have been assembled and delivered to users in the DD and EP Divisions.

The VALET software development consisted of an integration of PILS (Portable Interactive Language System) and libraries with VME, using all the cross-software tools recommended by the PRIAM project. The development has helped to debug the PRIAM tools and to provide expertise on VME, MC68000, cross-software, and debugging techniques.

CERNET has been implemented on the PRIAM UNIX VAX by installing the portable PASCAL transport manager in a front-end MC68000 running under RMS68K.

A portable system generation facility for RMS68K (Real-Time Multitasking for MC68000) was developed and installed on several hosts (VAX UNIX, VAX VMS, and ND-500). An integration of RMS68K with MoniCa was defined and an experimental version implemented. The portable MicroDAS has been installed under the experimental version of RMS68K integrated with MoniCa.

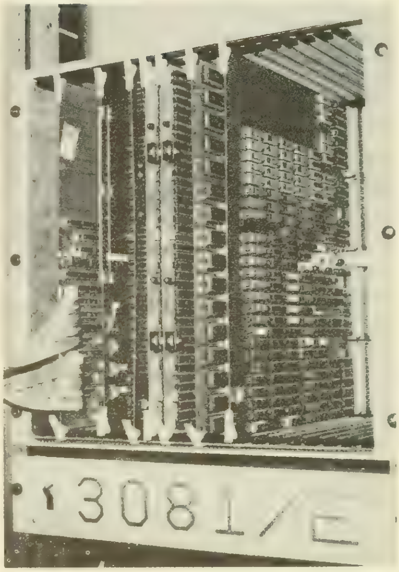
In the context of the PRIAM project, work has continued on the introduction of MC68000-based VME systems, with the evaluation of hardware from various manufacturers and the introduction of certain standard hardware into the CERN Stores.

Much work has been done on rationalizing the on-line computing documentation systems on the central IBM system under WYLBUR.

Five issues of the CERN Mini and Micro Computer Newsletter ('MMCNL') have been published between October 1983 and October 1984. The circulation of the MMCNL now amounts to some 1400 copies of each issue.

The HP and CAVIAR support continues at a fairly low level, but in spite of a reduction in the number

Figure 5 — One of the two prototypes of the 3081/E, an emulator of the IBM 3081, with far more power than its predecessor, the 168/E. An identical prototype was constructed simultaneously in collaboration with SLAC and is installed there. (CERN-253.08.84)



of HPs the support load is increasing owing to more complex applications of data acquisition in test beams. The CAMAC Booster (CAB) has been integrated in PS 177 and will soon be in CHARM II.

Emulators

168/E Off-Line Pool

The Pool continued in full production throughout the year with three clusters of two processors each. By the end of the year some 8000 jobs had been run, representing over 7000 hours of IBM 370/168 equivalent processing time. Peak usage has been 1200 equivalent hours per month, which represents more than one third of the work load of the combined IBM and Siemens Centre. The main user has been the R807 experiment, closely followed by the Split-Field Magnet (SFM), with smaller amounts of time going to NA12 and other users.

168/E On-Line

The number of 168/E processors installed for on-line filtering use at UA1 has been increased to six, and their program memory size has been doubled to allow more powerful and complex algorithms to be run. With increased $p\bar{p}$ luminosity, they are now actually being used for the rejection of events. All UA1 physics results so far have come from events selected by the 168/E filter.

As part of the upgrading of the UA1 data-acquisition system, a 4 Mbytes/s, 120 m long, VME/VMX-to-CAMAC link has been designed and two samples have been delivered. This allows transmission of event data from their new VME-based system to the 168/E array, whilst retaining the existing CAMAC-based system of data routing and processor control.

An on-line 168/E system has been delivered to UA2, and is now coming into use in a filtering mode similar to that at UA1. The system consists of two 168/E processors assembled from existing spares, along with the associated specially built Greyhound/PAX interfaces and modified REMUS readout. This development also involved the transportation of all the 168/E on-line support and diagnostic software from the Norsk Data environment at UA1 to that of the VAX at UA2. This was accomplished thanks to the good collaboration of UA2 personnel and welcome help from the UA1 experts.

3081/E

This successor to the 168/E is being produced in a balanced collaboration with SLAC in the USA. The first half of the year was taken up with an intensive detail design and construction effort. As well as two sets of the CERN-designed boards, copies of all but one of the SLAC-designed boards were built for use in the prototype at CERN. Each board was debugged individually as it became available, and the first prototype was brought together at SLAC in August within three weeks. In the meantime, the second prototype at CERN has now been brought up to the same standard.

Detailed FORTRAN simulations of the individual boards aided considerably in achieving correct operation. Test-bench software was developed to allow easy

interactive debugging of the processor, and extensive sets of stand-alone tests for the individual boards have been written. At SLAC the translator/linker software which performs the conversion from IBM object code to 3081/E microcode was brought into operation early enough to support the initial processor integration tests with translated diagnostics adapted from those developed for the 168/E. It is now coming to a level where translation of larger examples of FORTRAN code can be attempted.

Initial performance measurements on the processor with translated FORTRAN code are very encouraging, and it is clear that the design goal of at least one IBM 370/168 equivalent has been met. The production of five processors, using the same wire-wrap technique as that for the prototypes, has been started in order to satisfy the initial needs of the first users, such as UA1, NA34, L3, and DELPHI. Emphasis is now being put on the associated interface work required. The question of a FASTBUS-based router and scheduler (FPAX) is being studied in collaboration with Orsay and the University of Rome, whilst the University of Padua is ready to collaborate on VME interfacing. Further production commitments will be made by the end of the year.

Off-Line Farm Pilot Project

A project to build a cluster of five 3081/E processors attached to an IBM 4361 host has started. The aim is to evaluate the performance of the cluster for the bulk off-line processing of event data. This project has attracted collaboration from Saclay and from the INFN in Italy. The 4361 computer is on loan from IBM, as part of a joint IBM–CERN project on interfacing.

MICE

During 1984 six MICE machines were successfully used in a variety of applications. Since this autumn, two experiments using MICE have come to an end: WA1 and R704.

Fast Processors: XOP

The XOP prototype was finished ahead of schedule and operates according to its specifications. The machine is made up of a set of dedicated units, each tailored to a specific task, all working in parallel and controlled by a 160-bit wide micro-instruction word. In addition to the conventional instructions, special features aimed at FASTBUS operations and effective trigger and data reduction have been introduced. The arithmetic logic unit executes one triple operand instruction every 100 ns in scalar mode or every 50 ns in vector mode.

The data memory is divided into up to 8 parallel banks of 8 Kbytes, expandable to 16 Kbytes by chip replacement. Each bank has its own DMA port, interfaced either to FASTBUS or to LeCroy 'ECLINE'. The interface can handle 40 Mbytes/s, yielding an input capacity of 320 Mbytes/s for a full eight-port system, which is unmatched by any known comparable processor.

Development has been supported by a simulation in the ISPS language, and this was steadily refined throughout the year as work progressed.

The XOP control is done by an MC68000 microprocessor via VME. For this, the software has been written to load, debug, and run XOP programs from a local terminal. Eight XOPs can be controlled from one MC68000 system. A cross-assembler runs on IBM or VAX. Library functions have been written, as well as some benchmark programs. Preliminary results show 10–40 times faster execution when compared with an MC68000 (10 MHz clock).

The LEP experiment L3 has ordered two machines to be used for evaluation, with an option on four more later, and is now collaborating for software and hardware development.

FASTBUS

CERN/DD-built models of the high-performance CERN FASTBUS interface (CFI), which allows a host on CAMAC to access FASTBUS modules, were delivered to NA31, ALEPH, DELPHI, and Saclay.

The CFI is capable of performing block transfers on FASTBUS at 12 Mbytes/s, contains logic to execute sequences of FASTBUS operations, and can optionally buffer 128 Kbytes of data. In addition, special features include data formating, and the possibility of externally triggering a list of operations on FASTBUS and looping on one or several FASTBUS operations.

The CFI is now being produced and tested by a European manufacturer. The CERN support for these interfaces is handled within the present DD On-line

Computer Pool framework. The flexibility of the CFI design has been exploited by industry, which is generating both a VME to FASTBUS and a Norsk Data to FASTBUS interface. Implementations of a direct VAX to FASTBUS interface are under investigation.

The standard FASTBUS routines and test programs are now supported on VAX, MC68000, ND, and PDP host machines for FIORI (FASTBUS to I/O Register Interface), CFI, and Fast Sequencer interfaces and for a timing diagrams generator. The CFI has also been successfully incorporated into the NA31 VAX on-line system, and their first data-taking period was completed with only minor teething troubles. All hardware interfaces are at present driven by CAMAC or VME I/O registers.

Bi-weekly meetings have been held throughout the year with end-users, particularly with those from the LEP groups and with members of NA31 and the VIRTUS (Very Intelligent Real Time Event Selector) project. These meetings, which will continue, have been most fruitful in assessing priorities and in encouraging user production of portable general-purpose software.

Jointly with EP Division, a prototype Service Request Handler was designed and debugged. A suite of test programs was translated from FDL (FASTBUS Diagnostic Language) into PILS to commission standard Segment Interconnects (built at the University of Illinois). The close association with the ESONE and NIM FASTBUS Design Groups was continued. These groups are currently involved in a revision of the draft FASTBUS Software Standard for publication in 1985.

Direct Support to Experiments

LEP Experiments

ALEPH: The Division was involved in the planning of software specifications and design, and the evaluation of software design methodologies, program development tools, hardware/systems environments, and utility software.

A Monte Carlo program has been developed using the GEANT (Generation of Events ANd Tracks) package. The structuring, organization, and maintenance are done at CERN on IBM and VAX computers. The outside laboratories develop the software corresponding to the detector they have in their charge. An intensive test of HISTORIAN has been performed using the Monte Carlo program.

The prototype of the ADAMO (ALEPH DAta MOdel) data definition and manipulation system is under development. Its purpose is to define and manipulate symbolically the data structures from a FORTRAN program, without any knowledge of the underlying representation in memory or mass storage.

DELPHI: A big effort has been made to design a system to describe the detector. A structured data base, satisfying the specific requirements, has been proposed and implemented using KAPACK as the basic package. Tools have been provided to perform the standard data-base operations together with those required to export/import the detector description. All this software is being tested using the DELPHI simulation program, and new features (3D graphics etc.) are being implemented to make the system more general and complete.

L3: A time expansion chamber (TEC), which should serve as a prototype for the TEC of L3, is under construction for the Mark J experiment at DESY. For this chamber the Division has developed the electronics for reading out the track signals and their transmission over 60 m long cables. The 168 channels of this electronics are being constructed.

In view of a possible use of silicon microstrips as a complement to the TEC in L3, the Division collaborated in a silicon microstrip subgroup of the L3 central detector group. In collaboration with EF Division, DD has participated in setting up a clean room for the handling and testing of silicon microstrips and associated electronics. For this, two systems (based on VME and G64) for controlling the instruments were selected.

Special amplifier circuits were developed and realized using thick-film hybrid technology. For this purpose the necessary instruments for the prototype construction of such hybrids were installed at CERN. The volume production of these circuits in industry was supervised and they are now used by NA14, UA4, and biological institutes in Paris and Heidelberg.

There were continuing discussions with industry about the development of a CCD integrated circuit for the parallel-to-serial conversion of detector readout.

OPAL: The main contribution to the OPAL Collaboration has been in the area of pattern recognition in the central detector. For this purpose, a fairly realistic simulation of this detector has been developed and used to test a new method of track finding based on a conformal mapping of the data. The method is still in the development stage but, already now, is giving excellent results. It is expected that the method

can be tested on real data from a full-size prototype in the near future.

Collider Experiments

UA1: The software support to UA1 continued with the setting up of all on-line programs on the ND-500, the setting up of programs in the on-line 168E processors, and the setting up of 'BOL-type' software on the ND-500 for fast feedback to the experiment. In addition, monitoring and bookkeeping packages, together with calibration programs for the Central Detector, were provided. Support was given for all standard CERN packages on the ND-500.

The UA1 systems were linked with Norsk Data's local area network COSMOS, and the installation of an additional ND-100 at UA1 is in preparation, requiring careful planning to avoid disturbing their data-taking.

To improve the data-acquisition system, the industry-standard VME bus with MC68000 microprocessors is being introduced into the UA1 readout, monitoring, and supervision. As almost nothing in terms of hardware and software existed, a big development effort had to be made, which has led to a new set of VME modules. The Division contributed to the MacVEE project by developing the software for the MacIntosh computer.

UA2: All UA2 programs have now been converted to FORTRAN-77. The production, Monte Carlo, and DST programs have been implemented on the CDC 875, although the lack of memory still makes serious production running on this machine out of the question. Much effort has gone into speeding up the programs and reducing the amount of memory used.

The UA2 on-line graphics has been converted to use Mini-GD3. The filter program has been substantially altered, now performing calorimeter pattern recognition and more stringent software tests in order to reduce the amount of data needing further processing.

SPS Experiments

North Area: For NA9 and NA28 there remains low-level support for existing software. The new polarized target experiment has very modified hardware and this necessitated a complete rewrite of the pattern recognition program plus major modifications to all programs.

During spring and summer, the NA3 experiment has taken data for a gluino search. This new activity has required modifications in the software, mainly in the momentum calculation.

The final DST for the NA27 π data was produced by the summer, and physics papers are now beginning to appear. The most crucial detector for the physics aims of NA27 (the study of short-lived decays) is the vertex detector: the high-resolution bubble chamber LEBC. A correspondingly substantial amount of time has been devoted to the calibration of this device following the 1983 rebuild, and to tuning the vertex fit to exploit the increased resolution now available. The CERN ERASME on-line program has also been updated to give a higher throughput in order to finish the experiment before the scheduled ERASME close-down at the end of 1986.

A program was developed to analyse this year's test-run data of the CP-violation experiment NA31. In view of next year's serious data-taking, all calibration data as well as the geometry description are kept in a KAPACK data base. This data base is constructed to be portable to IBM, CDC, or VAX, using the EPIO package.

A general Monte Carlo simulation program was coded, allowing events to be written onto tape in the correct on-line EPIO format of the experiment. This program has to be fast enough to determine the small difference in acceptance of the K_L and K_S beams with a small statistical error.

The Division continued to be responsible for the maintenance of the on-line software and for the readout hardware which it constructed for the EHS spectrometer. In addition, direct support was given for the calorimeter electronics and their associated control software.

West Area: The neutrino experiment stopped data-taking in September. The pattern recognition program and the Monte Carlo program have been much used in production.

During the course of the year an unexpectedly high level of support has been given to the CHARM Collaboration in the final phases of the WA18/1 experiment. The last period of data-taking is now complete and the detector has been dismantled.

For the new experiment of the CHARM Collaboration (first test runs foreseen in 1985) it was decided to rewrite the on-line software for the new ND-100/500 system, to rewrite the off-line analysis program, introducing a memory manager, and to make all monitoring tasks, display programs, and ana-

lysis tasks use the same memory structure, thus making them available both on- and off-line. Also the beam-line monitoring is being changed.

For the Omega facility, work has been done on TRIDENT to deal with high track multiplicity events. This has led to improved methods for track finding. Modifications to the old Omega vertex package were necessary in order to fit up to 30 tracks to a vertex.

Miscellaneous Activities

Maintenance of the six ERASME measuring tables continued. Help was given to the Junta de Energia Nuclear in Madrid to revise their ERASME table.

The software package MDS from PCK for the multiwire technology has been acquired and adapted to the CERN environment. The system is installed on a VAX and has been made user friendly with an extensive command file. Plot files are sent over CERNET to the plotters on the mainframes in the Computer Centre. A dense VME board has been designed and successfully manufactured using this tool. Large, high-density boards for 3081/E and FASTBUS are currently being designed with this software.

An experiment to use the CMOS standard cell design methods in a Multi-Project Chip (MPC) environment is under way and results will soon be available. Meanwhile, work is being done to produce software tools to make the design and verification work more tractable and less error prone.

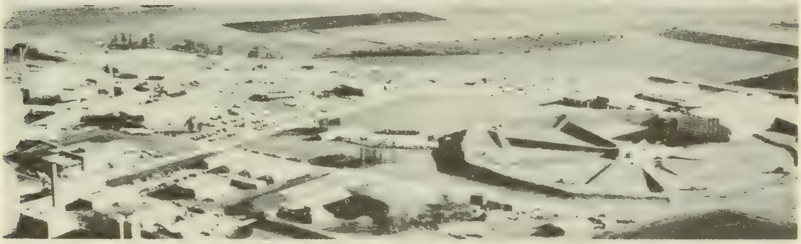
The modelling program SPICE was installed on the ERASME VAX. It will be used for developing special analog circuits.

Divisional staff continued to dedicate time to CERN's training efforts. Lectures were given in the Academic Training Programme and in the Summer Student Programme. Four staff taught in the Technical Training Programme. Special courses were given—amongst others, on data bases, CAD, and programming of Array Logic chips (PALs). The Division is responsible for organizing the Computer Seminars. The Informatics Tutorials continued to be a success; this year, courses on UNIX, Computer Architecture, and the C programming language were given.

The CERN School of Computing took place in September in Aiguablava, Spain. Besides the usual organizational efforts, the Division provided four lecturers. The School was attended by 86 participants from 10 countries. As a result of this success, it was decided to organize the CERN Schools of Computing on a yearly basis from 1986 onwards. The Division also continued to collaborate with the International Centre for Theoretical Physics in Trieste, organizing microprocessor courses. In 1984 a course was held in Sri Lanka.

Members of the staff also took part in the work of international standardization committees, notably for the new FORTRAN standard and for network protocols.

Proton Synchrotron Division



In the course of twenty-five years of continuous development around the accelerators, the PS area has become heavily built up, and the shape of the earth mound covering the original Ring building with its radial tunnels can only be made out with difficulty in this recent aerial photograph (above). By contrast, the picture taken in 1959 shows the machine looking as unnaturally neat and tidy as an architect's model. Of course, in that first year of operation there was no Booster Synchrotron, no second Linac, no East Experimental Hall, no Antiproton Accumulator and none of the various structures subsequently built to house additional equipment needed to support the versatile complex of accelerators into which the original Proton Synchrotron evolved over the years. (The later aerial view, looking in the opposite direction from the 1959 picture, was taken in 1983, the excavation in the foreground was in preparation for the LEP Preinjector buildings, occupying the space where the neutrino experiment beam tunnel stood for many years.) (CERN 1257 and 185.06.83)

Proton Synchrotron Division

Introduction

Celebrating its twenty-fifth anniversary of operation this year, the PS complex of accelerators had developed far beyond what might have been imagined when the pioneering alternating gradient synchrotron produced its first high energy protons in November of 1959. Early on in its career it acquired a second experimental area, the East Hall, and shortly afterwards there began the first improvement programme to increase beam intensities—by 1984, these had reached some ten thousand times the original design figure. There followed the highly successful antiproton programme, culminating in a triumph for experimental physics at CERN, based entirely upon obtaining a performance from the PS complex sufficiently reliable and efficient to make the search for rare events feasible. At the same time, the unparalleled flexibility of the machines and their control system enabled protons, antiprotons (and even light ions) over a wide range of energies and intensities to be supplied to several different users running their experiments concurrently. Nor, in 1984, had the process of development slowed down. Preparations were well under way for the acceleration of electrons and positrons to supply the new 'big brother' LEP, and a new device under construction (ACOL) was expected to multiply the antiproton accumulation rate by a factor of at least ten when it came on stream in 1987. So it was with justifiable pride that the twenty-fifth anniversary of this unique facility was duly celebrated, and the machines themselves had their say by creating new performance records whilst the feasting was still going on.

Although perhaps not quite so rich in drama as the preceding year, 1984 nevertheless had its triumphs. A systematic development programme throughout the complex resulted in a solid benefit to overall performance, so that Collider operation in the last running period achieved more than two-and-a-half times the integrated luminosity of the same period in 1983. LEAR was able to operate for a 24 hour day, and extended its range of available momenta, as well as preparing further developments (including the 'energy-scanning' mode) for 1985. The ISR were, after initial problems with a somewhat difficult form of operation for the PS, successfully supplied for—sadly—their very last experiment. Likewise, the final experiments in the long series of neutrino investigations using the PS got a good send-off. The original PS injector, Linac 1, underwent a renaissance, and preparations were under way to shift the whole machine to a healthier and more convenient location. The project for computerization of the PS controls system was completed, although developments since the original plans were drawn up meant that the conversion programme continued. At the Synchro-Cyclotron a full range of light ions was available to experimenters for the first time. Installations for the second on-line isotope separator (ISOLDE 3) were proceeding, and preparations were in hand to increase the proton and helium ion beam intensities. Both the LEP Preinjector project and the design of the new Antiproton Collector (ACOL) made good progress.

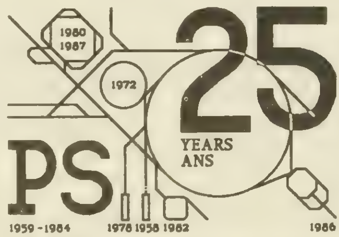


Figure 1—25th anniversary emblem, showing the development of the accelerator complex; 1958: 50 MeV protons (Linac I); 1959: protons at GeV energies (PS); 1972: injection to PS at 800 MeV (Booster); 1978: further increase in beam intensity (Linac II) ; 1980: cooled $\bar{p}$ in production (AA); 1982: steady streams of pure low-energy $\bar{p}$ from LEAR. For the future: 1986: e^+ and e^- from the LEP-preinjector; 1987: order of magnitude increase in $\bar{p}$ production with ACOL.

PROTON SYNCHROTRON

The Physics Programme

Operation

1984 saw the end of a long and fruitful association when the ISR finally took its last supply of PS particles. A sad day, but not entirely without its compensations, for the difficult task of scheduling the many different users was significantly simplified. Another era ended when the last of the many neutrino experiments finished its run in July. Whilst perhaps not so spectacular as 1983, the year yielded its share of new record performances.

The year began with the usual long shutdown and, among all the other work which had accumulated during the almost continuous operation of the previous twelve months, major changes were made to the radiation safety and access control system. Transfer of displays and controls to a new console in the Main Control Room made it necessary to reconstruct the interlock chains, and the opportunity was taken to use more modern components and techniques, besides generally reviewing the logic. At the same time an additional interlock facility, intended to be a safeguard against possible faulty procedures, was introduced on 80 doors. Some manufacturing delays by contractors, and a few wrong cable connections (more than 18,000 points were modified!) hindered the essential thorough checking and testing programme required to establish a fully safe situation, and it was decided to delay the procedure for starting up the accelerators by ten days.

To minimize the effect of the delay on the experimental programme, purely technical aspects of starting up the accelerators were cut down to the absolute essentials. Predictably, the newly-computerized controls for beam extraction and transfer suffered some teething troubles, and matters were not helped by three failures of the incoming electricity supply. A good deal of hard work was put in by all concerned and, adopting the strategy of getting things going first and optimizing later, no fewer than 11 different kinds of beam were produced during the first month, including antiprotons at 3.5 GeV/c for the last runs of the ISR and decelerated antiprotons at 0.6 GeV/c for LEAR. Providing antiprotons for the ISR at AA momentum, i.e. using the PS as a transfer line, proved a tricky process to adjust and maintain, and there were some difficulties in getting a large enough ISR stack to satisfy the experiments which were taking data. Since LEAR experiments were in direct competition for the limited supply of antiprotons available, rather delicate negotiations took place on a day-to-day basis to try to ensure that everyone got their fair share. The new possibility of supplying LEAR with only a short interruption in antiproton production, enabling that machine to run on a 24 hours per day basis, helped somewhat, and the reproducibility of the 3.5 GeV/c transfer was eventually improved by using the same magnet cycle as for deceleration for LEAR. Performance steadily improved, and in April the transfer momentum of protons to the SPS was put up from 10 to 14 GeV/c, significantly increasing the overall efficiency of the process.

Figure 2 — Overall distribution of protons and antiprotons in 1984.

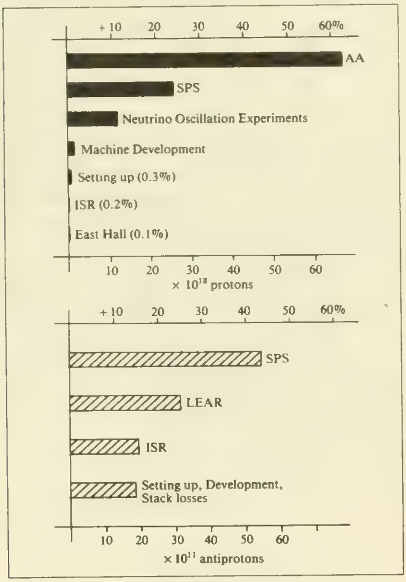
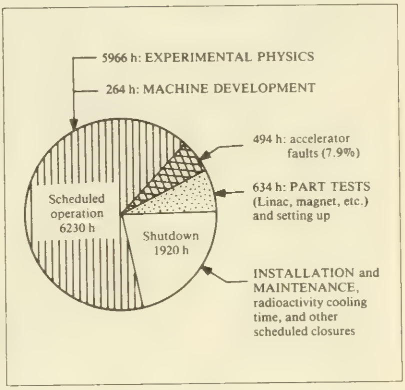


Figure 3 — Functional division of the PS year (24 hours per day).



In May, after early difficulties once again due to electricity supply failures, performance reached a steady level equivalent to the best obtained in the preceding month. The 3.5 GeV/c transfers to the ISR became quite efficient, and stored beams of 5 mA were regularly produced. Transfer to the SPS at 14 GeV/c became routine and, supplied with 2×10^{13} protons per cycle, that machine shortly reached new record intensities (passing the 'magic' figure of $\pi \times 10^{13}$ accelerated protons). Antiproton extraction from LEAR at 1.5 GeV/c came into service in a remarkably short time. Unfortunately, development work on the machines was seriously disturbed by a fault on the AA magnetic focusing horn. In June, operation was somewhat troubled by the effect of summer storms on the power lines; the ISR lost their antiproton stack, and an unscheduled special refill had to be provided so that experiment R704 could complete its data and retire gracefully from the scene. Protons once again became available for the many users of the East Hall test beams.

Although July began well, the situation shortly deteriorated, and there were numerous breakdowns. The worst trouble was caused by sporadic misfunction of two key systems, one controlling transfer of PS beam in all directions and the other the sequence of parameter switching for the programmed magnet cycles. So much time was lost that it was eventually decided to extend the last run for the neutrino oscillations experiments by two weeks and to postpone the scheduled machine development sessions. Towards the end of the month the AA came back into service after two weeks of development work and tests, with a new pulsed target and a lithium lens to focus the proton beam on to it. Antiproton yield was up by some 50%, but unfortunately the target only lived for a day and a night; the lens, however, kept going. LEAR had, as predicted, a difficult time setting up extraction at the new momentum of 200 MeV/c.

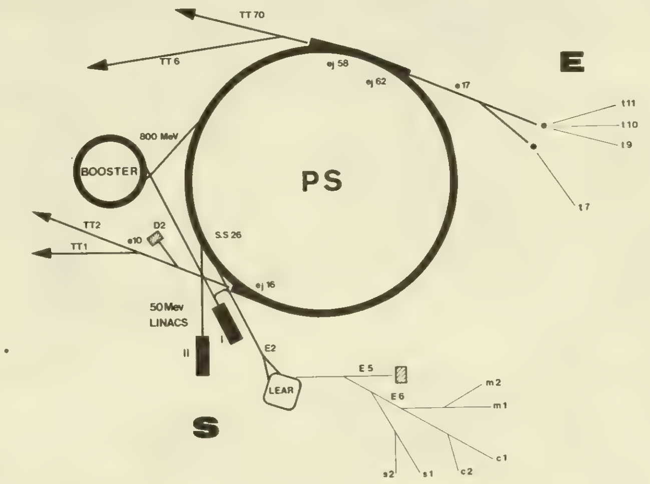
In August the fault rate diminished, but still remained higher than average. There was trouble with cooling water systems, HT feeds to the Booster extraction kicker and, rather more esoterically, disturbances caused by unexpected effects of the ISR dismantling. Computer-controlled synchronization, still being run in, also gave some problems. However, the run of the neutrino oscillations experiment was successfully completed, with 8.7×10^{18} protons having been delivered to the target, and the bubble chamber BEBC having taken more than half a million pictures. The efficiency of utilization was enhanced by the use of systematic supercycle changes, so that LEAR and the East Hall got a good share of the beam available. (N.B. For an explanation of supercycle operation, see the Annual Report for 1983, p. 79.) At the end of the month a week was spent, in collaboration with the SPS, in preparing for the forthcoming important proton–antiproton collider operation.

Setting-up of the machines for the collider run went rather well, and data-taking by the SPS experimenters began before the end of September. Overall efficiency and beam quality reached the best levels obtained in 1983 and stayed there. A short stop in order to make adjustments to the AA stochastic cooling systems quickly paid dividends in the shape of a substantial increase in the antiproton accumulation rate. With a production beam of 1.4×10^{13} protons striking the target every 2.4 seconds, peak values of more than 6×10^9 $\bar{p}$/hour were recorded, and after 40 days the integrated luminosity reached in the SPS was two-and-a-half times greater than for the equivalent period in 1983. However, the smooth running of the AA was interrupted on several occasions by a mysterious blow-up occurring in the accumulated stack. The East Hall beams, having a relatively low priority, lost some of their scheduled time to studies aimed at further improving collider operation.

The fault rate in October remained low until the end of the month, when a stop scheduled for technical reasons had to be unexpectedly extended from two days to five. This was due to a leak in the heat exchanger of the main magnet generator lubricating system, and the unit had to be replaced. November was a highly satisfactory month; even without its lithium lens, the AA maintained an excellent performance, with accumulation rates normally above 6×10^9 $\bar{p}$/hour and reaching a peak of 7×10^9. Overall transfer efficiency between the AA and the SPS frequently hit 80%, and new high values of luminosity at 315 GeV/c resulted. Despite numerous schedule changes, the East Hall beams eventually got the total running time allocated. LEAR made its first tests with H^- ions (supplied by Linac I) and, returning to protons, tried out deceleration down to 100 MeV/c; this worked, but stability was inadequate.

With impeccable timing, the PS celebrated its 25th birthday on November 23rd by breaking two records — it delivered 1.6×10^{13} protons per pulse to the production target, and the circulating beam in the AA reached 3.87×10^{11} antiprotons. Finally, in December, the causes of the mysterious stack blow-up in the AA were diagnosed and curative measures were

Figure 4—Schematic diagram of the PS beams and experimental complexes in 1984.



LINACS I AND II

Either Linac can supply the Booster, or the PS directly, with 50 MeV protons; Linac II is normally used for regular operation. Linac I also provides a proton test beam and H^- ions for LEAR.

SOUTH HALL (S)

LEAR, the low energy antiproton ring, is designed to provide pure beams of "cooled" antiprotons between 0.1 and 2 GeV/c for an experimental area occupying the remainder of the South Hall.*

E2 : *supplies LEAR with 50 MeV protons and H^- ions from Linac I, or with antiprotons at 0.6 GeV/c extracted from straight section 26 in the PS.*

E5 : *extracted beam line from LEAR fitted with equipment to measure beam characteristics.*

E6 : *supplies the experimental areas with continuous streams of antiprotons extracted from the LEAR stack at a rate of about 3×10^5 $\bar{p}$/s. The beam is divided into three branches, each of which can be directed into one of two paths leading to different experimental zones. Relative intensity in the three main branches is adjustable over a range of 20:1. Beams m_1, c_1 and c_2 can operate at up to 2 GeV/c, and beams m_2, s_1 and s_2 at up to about 1 GeV/c.*

TRANSFER TUNNELS (TT)

TT1 : *takes proton beams to the ISR Ring II; a branch TT7 (not shown) supplies the target for the "neutrino oscillation" experiments (PS169, 180, and 181).*

TT2 : *takes proton beams for the ISR Ring I and for the SPS (via TT10, not shown). It also carries protons for $\bar{p}$ production and for test purposes to the Antiproton Accumulator (AA), and antiprotons returning from the AA to the PS at 3.5 GeV/c.*

TT6 : *supplies antiprotons from the PS to ISR Ring II.*

TT70 : *takes antiprotons accelerated in the PS to the SPS for collider experiments; protons can be sent in the opposite direction to check out the beam transport line.*

D2 : *external dump buried in the earth outside the Ring wall; used for setting up the beams travelling along TT1 and TT2, and also during PS machine development sessions.*

EAST HALL (E)

Slow extraction from straight-section 62; the primary beam, e_{17}, is divided into two branches and targets in each of these provide four secondary beams. The latter can supply intensities of about 10^5 hadrons (or 10^3-10^4 e^+e^-, depending upon momentum), for 10^{11} protons of 24 GeV/c on target, with $\Delta p/p \sim 1\%$. Beams t_7 and t_9 can operate at up to 10 GeV/c, and t_{10} and t_{11} at up to 5 and 3.5 GeV/c respectively.

taken. The collider run proved to have been extremely successful — integrated luminosity in the SPS surpassed the target figure by some 30%, reaching 395.4 $nbarn^{-1}$, or a factor of 2.6 higher than in 1983.

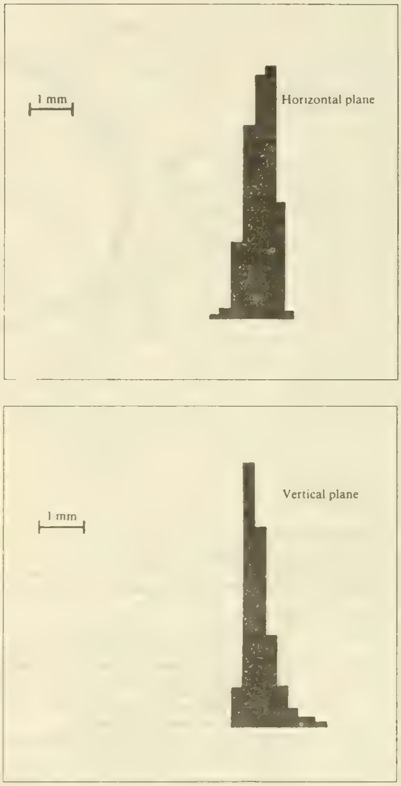
Experimental Areas

In the PS South Hall, entirely devoted to experiments using the pure low-energy antiproton beams provided by LEAR (q.v.), some improvements were made to the installations during the long shutdown at the beginning of the year. Some vacuum chambers inside magnets were replaced by a more suitable material (stainless steel instead of aluminium alloy), some of the multiwire proportional chambers employed for beam control were repositioned, and the computer acquisition of monitor measurements was improved. New fire and gas detection systems were installed.

From March to September the sixteen experiments installed on the floor received a total of about 690 hours of experimental physics beam time. A new operational mode had become possible, enabling LEAR to function 24 hours per day whilst antiproton accumulation in the AA continued almost uninterrupted. The extracted beam spill duration was about one hour, providing intensities of up to ~ 10^5 $\bar{p}$/s for the three experiments usually working simultaneously, two splitter magnets being used to divide the beam. Frequent changeovers were made to give all the experiments a fair share. Five different momenta were available, namely: 201, 310, 612, 1480 and 1512 MeV/c. At the lowest momentum of 201 MeV/c there were beam stability problems both in the machine and in the transfer lines. Nevertheless, quality was good; for example, at 310 MeV/c the beam was focused down to a spot size of around 1 mm^2 (Expt. PS 177) and an even smaller dimension was achieved at 1512 MeV/c (Expt. PS 185 – see Fig. 5).

No protons were available for the East Hall extracted beam until June. Consequently the first part of the year could be used to complete the distribution network for various gases and the gas and fire detection systems in the primary beam tunnels. The approved continuation of experiment PS 188 required some beam and layout modifications, and in the beam line (t_7) magnet measurements and alignment checks were made in order to resolve some discrepancies in momentum measurements. Beam transport elements were overhauled and exchanged to provide the elements for the new LEAR injection line (E3).

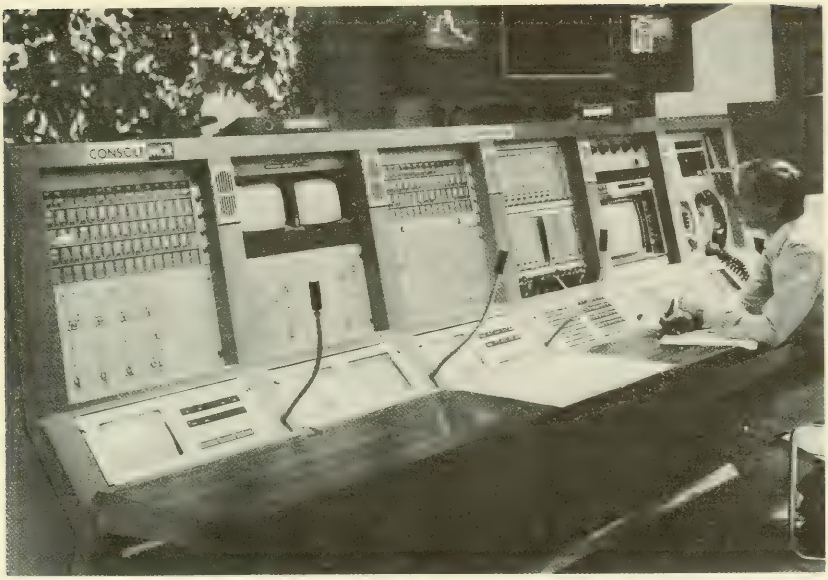
Figure 5 — LEAR Experimental area. Beam profile measured at PS185 focus.
Resolution: 0.25 mm/bin
Intensity: ≈ 10^5 antiprotons/second
p: 1.5 GeV/c.



From June onwards, protons became available for the East Hall for a part of each weekday. The three test beams (t_9, t_{10} and t_{11}) were extensively used for tests of equipment for various SPS experiments and also development work on detectors for LEP experiments. Experiment PS 188 ('channelling') continued taking data in the t_7 beam.

The last run of the beam specially built (in TT7) for the neutrino oscillations experiments took place in

Figure 6—The new Security Console in the PS Main Control Room. Television monitors used for access control and operational information can be seen, and above them the interlock logic chains governing the supply of beams to the different security zones. On the wall behind are monitors showing information being supplied to PS and SPS users, and a diagram of beam flow throughout the complex, indicating the presence of obstacles such as monitoring screens, vacuum valves, etc. (CERN-24.10.1984)



July. As in 1983, the target received ~ 1.25×10^{13} protons of 19.2 GeV/c every 1.2 seconds. The bubble chamber BEBC completed its data-taking (PS 180), and a new experiment (PS 191 - Search for decay of heavy neutrinos) also took data with detectors placed in the ISR intersection region I1.

Machines and Technical Development

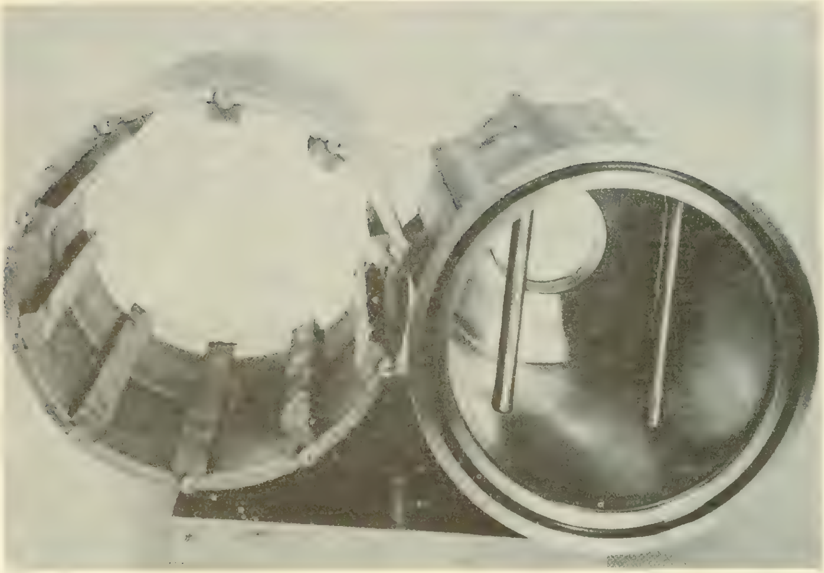
Linear Accelerators

Linac II, proton supplier for the whole PS complex, ran reliably without any major problems. The new cleaning technique adopted in 1983 for the 750 keV preinjector accelerating column proved its worth; reliable high voltage operation was maintained throughout 1984. Another innovation which justified the effort put into it was the control system 'watchdog' program. This stopped the ion source trigger whenever beam losses in the linac or transport lines became too high, and informed the operator what had caused the abnormality. Several times during the year it saved the vacuum pipe from being hit by a 50 MeV beam which might well have holed it. Some improvements were made to the machine instrumentation, and deuteron acceleration tests were successfully performed.

First steps were taken in the direction of operating both linacs (and LEAR, which shared the controls system) from the PS Main Control Room. A link was established between the Linac-LEAR computers and the main PS control system, and controls for the essential elements of the Linac II—Booster beam transport line were incorporated into the PS controls.

This year saw a good deal of activity around Linac I (the original PS injector). Most noticeable was the replacement of the 500 kV EHT set, with its huge Faraday cage, and the preinjector accelerating

Figure 7—The decapole confinement magnet and plasma chamber of the new volume production H^- ion source for Linac I. The two vertical bars in the picture produce a dipolar magnetic field in the plasma, which enhances the production of H^- ions by dissociative attachment on highly excited hydrogen molecules. A thermionic cathode is mounted in the aperture seen at the rear. (CERN-538.02.1985)



column, by the relatively inconspicuous 'RFQ', to supply the accelerator with 500 keV particles. (For further information on the RFQ, see 1983 Annual Report, page 85.) An H^- ion source of the 'bucket' type was tested towards the end of the year, and resulted in beam pulses of 80 μs and more than 1 mA. Preparations for the acceleration of O^{6+} ions were rapidly going ahead, and a scheme was adopted which should allow for a quick changeover between these particles and protons or H^- ions.

The considerable saving in space resulting from the installation of the RFQ made it possible to plan an important change for the better in the whole machine layout in the congested area where the two linacs and the LEAR beam transport tunnel met the PS Ring. The shielding wall marking the boundary of the Ring was situated half-way along Linac I, straddling one of the accelerating cavities (Tank 2). By shifting the whole Linac back some twelve metres, it would become completely accessible during PS operation, and, moreover, the rather weak shielding, in an area crossed by high intensity extracted beams, could be considerably reinforced. Plans were made to complete the essential part of this scheme during the shutdown early in 1985.

Booster Synchrotron

In order to maintain its high performance and low failure rate over the years, the Booster has undergone a continuous process of rejuvenation. In 1984, it was the turn of the ageing control circuitry of the main magnet power supply, and the five rectifier-inverter groups were converted to control by programmable logic devices during the long shutdown at the beginning of the year.

The record intensity of 10^{13} protons reached in each of two of the four Booster rings was beneficial for antiproton production, since it enabled a high in-

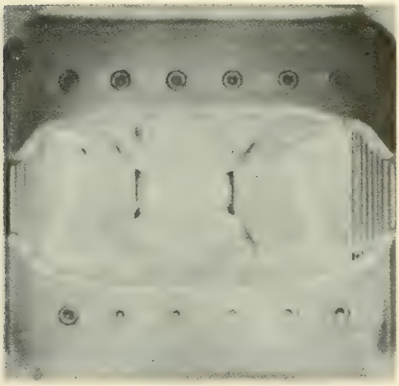


Figure 8 — The r.f. dipole, designed to assemble beams from the four separate Booster rings appropriately for injection into the PS. The structure is resonant at the bunch frequency of 8 MHz. Currents at this frequency flowing in opposite directions in the top and bottom conductors create a magnetic field providing the correct vertical deflection to direct the bunches arriving at different times and angles from each ring in sequence along the horizontal axis towards the PS. (CERN-791.11.1983)

tensity beam to be sent to the AA target without using any lossy form of recombination prior to injection into the PS. Taking beam from just two Booster rings, without the vertical addition process previously in use, markedly reduced losses in PSB–PS transfer, and produced a beam of higher intensity with smaller dimensions and emittances, resulting in more efficient antiproton production.

A further development towards even higher intensity antiproton production beams was installed and successfully tested. This used a dipole in the transfer line, giving a sinusoidal vertical deflection at the bunch frequency of 8 MHz, to combine beams from pairs of rings in somewhat the same way that a zip fastener works. It was tried out in machine development sessions, and met its specification after optimization of various parameters. In practice, the scheme would use the full four-ring Booster beam, trapping 20 PSB bunches in 10 PS buckets. However, it was not put into operational service, since the maximum intensity that the PS could accept currently was readily available from two of the Booster rings.

Following the previous year's very successful operation with deuterons and alpha particles (for the late lamented ISR), development work began on the project for accelerating very low intensity beams of oxygen (O^{8+}) ions. With different cycles devoted to different users, this would mean that an intensity variation of five orders of magnitude between one pulse and another would have to be handled. It was anticipated that considerable effort would have to be invested, particularly in the areas of instrumentation and r.f. control loops.

Investigations into the feasibility of increasing the Booster top energy to more than 800 MeV culminated in a successful test in one ring showing that 1 GeV could be reached. This had some importance for future developments, since space-charge limitations in the PS could be eased by using a higher injection energy.

Main Proton Synchrotron

Plans were made for the rearrangement of equipment in the PS straight sections to allow for the installation of equipment for injection, acceleration and extraction of electrons and positrons; it was intended to implement these during shutdown periods in 1985 and early 1986. The prototype Robinson wiggler magnet (required to stabilize electron and positron beams), after beam optics tests with protons in the PS, went to Orsay for further tests with a positron beam. These confirmed the damping effect predicted by theory, so that construction of the three magnets of this type to be installed in the PS could go ahead.

A new quadrupole configuration was devised, combining the existing quadrupoles in straight-sections 5 and 25 with additional units placed in s-s 49 and s-s 65, in order to reduce the horizontal beta

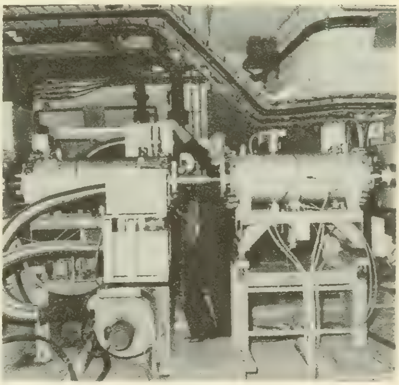


Figure 9 — Main components of the system designed to damp oscillations occurring during antiproton injection into the PS at 3.5 GeV/c. The high sensitivity pick-up is on the right and the electromagnetic deflector, with its power amplifiers, on the left. The damper was successful in conserving transverse emittances of the AA antiproton beam for onward transmission to the SPS at 26 GeV/c, with values as low as 10 π mm mrad horizontally and 7 π mm mrad vertically regularly recorded. (CERN-385.9.1984)

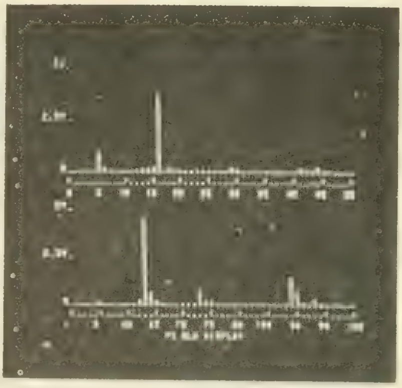


Figure 10—Computerized display of comparative beam losses monitored at 100 points around the PS ring. The system was running at high gain, and the actual losses represent only a small fraction of the circulating beam. A simple mode of operation was in use, supplying the Antiproton Accumulator with 10^{13} 26 GeV/c protons per pulse. The loss at extraction from straight-section 16 is clearly visible; the other loss points correspond to minima in the effective aperture of the machine. (Polaroid 07.03.1985)

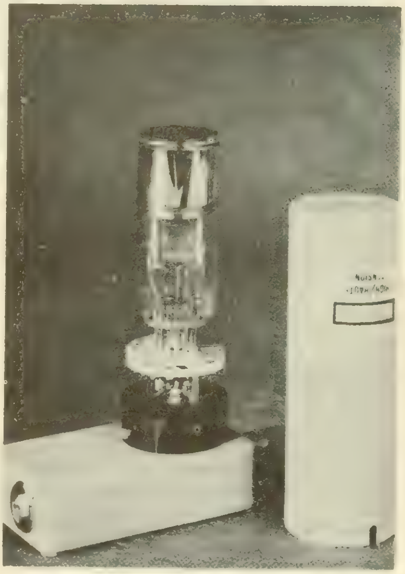


Figure 11—The 'ACEM'—Aluminium Cathode Electron Multiplier—used to monitor beam losses in the PS and the Booster. (CERN–491.11.1984)

functions and dispersion values at the points where protons and antiprotons are extracted (s-s 16 and s-s 58 respectively) for transfer to the SPS. It was expected that the resultant reduction in horizontal beam dimensions would increase extraction efficiency and also produce a kick enhancement effect, reducing the required kicker strength by 35%.

Random steering errors of a few millimetres at injection into the PS of the antiproton bunches destined for the SPS could lead to transverse emittance blow-up of more than 50%. It was decided to install a damper to reduce this effect, using a very sensitive pick-up to detect horizontal and vertical oscillations. The resulting signals, after amplification, were fed to an electromagnetic deflector with the correct phase and time-delay to counteract the oscillations. The apparatus was built in a very short time, to be ready for the Collider run starting in September, and it performed well, reducing emittance blow-up to less than 10%.

Considerable development work went into the various systems acquiring information on beam position, phase, etc., through pick-up electrodes. This was necessary in order to be able to cope with the wide range of intensities and bunch lengths encountered in present and future operation, as well as to control the acceleration of numerous different kinds of particle in the machine (e.g. p, $\bar{p}$, e^-, e^+, α, d, O^{8+}).

Results of radioactivity measurements showed that both the total and the average induced activity in the PS Ring were 20% lower in 1983 than in 1982, despite an increase of 10% in the number of protons accelerated. Computer control of the beam loss monitoring system provided a continuous display of the comparative losses at 100 points around the PS ring. This system was based on the 'ACEM' detector, in which electrons expelled from an aluminium cathode by radiation are fed directly into a ten-stage electron multiplier, whose gain can be readily controlled. It had the twin advantages of a wide dynamic range ($\sim 10^6$) and high radiation resistance. (N.B. A similar system was also installed in the Booster.)

Antiproton Accumulator

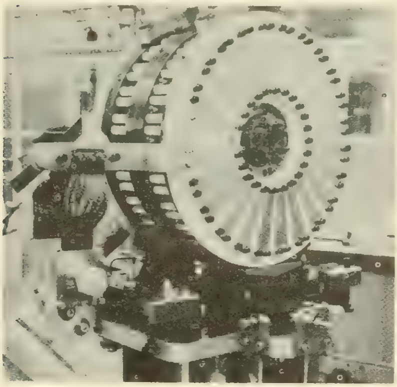
Performance of the AA during 1984 was very satisfactory. It operated for 5800 hours, with a downtime of no more than 13%, producing over 12×10^{12} antiprotons. The biggest stack built held 3.87×10^{11} $\bar{p}$ —incidentally, a world record.

Figure 12 — Following pioneering work at Novosibirsk, lithium lenses (using current flowing in the light metal to focus particle beams passing through it), were designed and constructed at Fermilab. One of these was brought to CERN, and first tested downstream of the AA target to concentrate the antiprotons, with good results. Subsequently the pulse transformer was rebuilt to increase its radiation resistance, and the device was installed ahead of the target to focus protons; again the tests were successful. In the picture the 23-turn primary of the pulse transformer is prominent; the lithium cylinder (20 × 150 mm) forming the secondary fits into the central aperture. (Photo C.D. Johnson)

Modifications to the applications software made it possible to change from the stacking mode to the extraction mode in a matter of minutes. The emittance program became able to derive values for the stack core as well as the average through the whole stack from the transverse Schottky signals. A scheme for automatic steering of the injected antiprotons was implemented. The control signals were derived from the electrons produced at the same time as the antiprotons, which had a similar envelope of coherent oscillations.

A second sextupole was installed in a dispersion-free straight section in order to diminish the losses of particles with large oscillation amplitudes. The space was liberated at the expense of a more elaborate system of connections to the adjacent cooling kicker electrodes. This produced a 10% increase in the stacking rate.

The filter lines for phase correction of the 1–2 GHz stack-core cooling were temperature-stabilized and provided with remote control for adjustments. This led to a much better transverse cooling performance. Even with an intensity of 3×10^{11} particles, transverse emittances of between 1.2 and 2.5 π mm mrad were usually obtained, and at lower intensities emittances in both directions were below 2π mm mrad. Core emittances during the stacking process were also markedly improved by correcting the field alignment in some of the kicker modules. It was these developments, together with improvements to the filter lines, which essentially made LEAR operation for 24 hours per day possible. Some experiments were also carried out on pre-cooling, but little of operational benefit emerged.



In autumn an inexplicable transverse beam blow-up manifested itself on many occasions, especially at the high stack intensities required for SPS collider operation. Investigations, carried out under the constraint of maintaining normal operation throughout, eventually identified three different mechanisms. All three resulted from inadequate clearing of positive ions trapped in the beam at high stack intensities, indicating that the clearing electrode system would need some modifications. Further studies were devoted to trying to identify other sources of 'heating' during the stacking process.

The lithium lens transformer (ex Fermilab) was rebuilt with a more radiation-resistant primary winding, and successful laboratory tests took place in May with lens currents of up to 475 kA. The transformer-lens assembly was then installed as a pre-focusing element in front of the target and ran with pulsed currents of between 290 and 350 kA. It operated successfully for a total of 1.3×10^6 pulses in a 26 GeV/c beam of up to 1.4×10^{13} protons per pulse before being withdrawn from service, still fully operational.

For the Antiproton Collector project (ACOL — see Annual Report for 1983 page 93), major contracts for the magnet system were placed. Delivery of the first quadrupole was expected early in 1985 and of the first dipole around the middle of the year. Design of the vacuum system was completed and tenders were being requested. Development of stochastic cooling systems and solid state amplifiers was under way with the construction of prototypes. Building work had begun with the auxiliary building above the target area, which was expected to reach completion in bruary 1985.

LEAR

During two shutdown periods, one early in the year when the PS was also not running and the second in October, various modifications were carried out to consolidate current modes of operation and prepare for future developments. Among the most important was the installation of a new injection line for negative hydrogen ions (H^-), fast pulsed dipole magnets and special thin targets. This was intended to provide protons travelling in the opposite direction from the anti-

protons by injecting H^- into a straight section and then stripping them of their electrons by passage through the thin target. Suitable means of monitoring this process, by the observation of slow secondary emission electrons, fast electrons from stripping, hydrogen (H^0) atoms, etc., were provided. Thin windows (35 μm) were also fitted at the ends of the straight sections as H^0 exits. The second r.f. cavity was installed, and when all this work was finished the vacuum envelope was thoroughly baked out.

Modifications were made to the dipole and quadrupole power supplies to improve stability when operating at low momentum, since these units had to work over an exceptionally wide range of current. The associated electronic control systems required special components and air conditioning to cope with the heat of summer. Two improvements were made to the stochastic cooling systems. The horizontal deflector was moved to a more favourable position with respect to its detector, and a horizontal deflector was added to the momentum cooling system to eliminate the transverse blow-up effect occurring because the derivative of the dispersion function was not zero at this location. The stochastic extraction system was modified to increase the noise level at the peak of the resonance and reduce it at the edges. This considerably cut down the (mainly 50 Hz) ripple on the extracted beam, and enabled duty factors of 80% or higher to be achieved.

Various developments took place in the computerized control system, covering machine operation, editor programs for the function generators and timing system, extracted beam settings and beam quality measurements.

Principal machine studies were concentrated on using protons to develop the operational techniques required by the experimental programme. Preparations were made for the energy scanning mode of operation. Priority was also given to investigating behaviour at low momentum (around 100 MeV/c), particularly the combined effect of residual gas, non-linear resonances and intra-beam scattering. Unfortunately, the extent to which these studies could be pursued was severely limited by various breakdowns of the LEAR r.f. system and of Linac I which occurred towards the end of the year.

The extraction system regularly produced stable streams of an hour's duration, and it was shown experimentally that this could be extended to three hours at intermediate energies. Tests with H^- ions showed that the charge-exchange process for proton injection would work, and that the H^- lifetime in LEAR was limited (at 300 MeV/c) by the vacuum obtainable; further work awaited provision of a stable ion beam with the new H^- source under development.

The most important feature of operation for experimental physics throughout 1984 was the ability to run almost continuously with beam extracted for an hour followed by fifteen minutes refill time, which meant that more ambitious parallel running schemes could be planned for 1985. In summer, operation at low momentum (~ 200 MeV/c) was seriously disturbed by the power supply problems already mentioned. The reliability of the machine was essentially very good, most interruptions being associated with the frequent introduction of new modes of operation. Machine development time was restricted severely in order that the experimental programme should suffer as little as possible from the frequent changes in the PS schedule, often occurring at very short notice. It became very evident that the physics programme would greatly benefit from longer uninterrupted periods without changes. (See also 'Operation' and 'Experimental Areas' above.)

Developments in Overall Performance

Development continued of the beam used for antiproton production, employing a PS magnetic field cycle with a low rate of rise at injection (0.1 T s^{-1} instead of 0.6 T s^{-1}) followed almost immediately by a plateau for the low-energy controlled longitudinal expansion. Transfer between Booster and PS rapidly showed a marked improvement, an important parameter being the r.f. voltage at injection, which it was found possible to bring down to the theoretical value for matching to the Booster bunches (~ 30 kV); this considerably reduced low energy beam losses. The new magnetic field cycle therefore remained in use for normal operation, sharing a supercycle with others having the standard rate of rise of field at injection, which entailed adjusting injection and low-energy expansion parameters from cycle to cycie.

Using this same magnetic field cycle, a systematic study was made of the resonances straddled by the high intensity bunches and of their compensation. At the same time, the poleface winding current programme was correctly adjusted up to 26 GeV/c to avoid crossing dangerous resonances during acceleration, and the fast extraction was set up in the presence of the strong chromaticity resulting from this programme. The combined outcome of these various

measures was a steady increase in beam intensity on the AA production target together with a higher transmission efficiency between Booster and PS and a marked reduction in transverse emittance of the beam. Thus, during SPS collider operation, the beam destined for the antiproton production target had an intensity of between 1.50 and 1.55 $\times 10^{13}$ protons per pulse (and a maximum of 1.6 $\times 10^{13}$) with normalized emittances of 90π mm mrad (horizontal) and 60π mm mrad (vertical), and this high quality performance was obtained with beam losses between Booster and PS of no more than 1.5 $\times 10^{12}$ protons per pulse.

Using once again this same magnetic field cycle, studies were made of the behaviour of the beams from two Booster rings when recombined by the r.f. dipole installed at the beginning of the year. This technique was designed to increase antiproton production beam intensity in the future by using beam from the four Booster rings captured at 800 MeV in two groups of five r.f. buckets diametrically opposed in the PS, allowing continued use of the current method of reduction to five bunches by merging longitudinally at 26 GeV/c.

The capture of two Booster bunches with an r.f. phase separation of $\pm 80°$ in a single PS bucket, required for the technique described above, was tried out. Using a low r.f. voltage at injection, rapidly increased over the first 5 ms, gave the maximum capture efficiency. This would produce, at 26 GeV/c in the PS, 7–7.5 $\times 10^{12}$ protons per pulse for 8.5–9.5 $\times 10^{12}$ ppp from two Booster rings. The best stable and reproducible result obtained, 7 $\times 10^{12}$ ppp accelerated for 8.5 $\times 10^{12}$ presented, was maintained for a variation in the phase between bunches from $\pm 90°$ to $\pm 70°$.

The technique therefore appeared to be limited neither by vertical emittance nor by capture problems. However, increasing the Booster intensity merely pushed up low energy beam losses, and there was scarcely any increase in the intensity accelerated. The beam produced by this method would hence be less than the 1.5 $\times 10^{12}$ protons per bunch of the standard high intensity beam, and the limitation appeared to be due to microwave longitudinal instabilities during threading into the r.f. bucket.

A new and different procedure was tried out for the future production beam for the Antiproton Collector (ACOL—see elsewhere and 1983 Annual Report p. 93). This would involve combining ten bunches into five whilst changing the r.f. harmonic number from 20 to 10, and subsequently going back progressively through 12, 14, 16 and 18 to arrive at h = 20 with five bunches occupying one quarter of the PS circumference. The first step was tried out with a low intensity beam (50 $\times 10^{11}$ ppp) at 3.5 GeV/c, and functioned correctly. A second series of tests, with the r.f. voltage reduced by connecting pairs of accelerating cavities in opposite phase, began the process of reducing the distance between bunches resulting from the harmonic number changes from 10 to 12 and then 14. These were also carried out on a 3.5 GeV/c field flat top and at low intensity ($\sim 2 \times 10^{12}$ ppp). The behaviour of the beam was much as expected, and on the basis of these tests construction of beam control equipment for further work went ahead. Interest was also confirmed in plans for local feedback on the r.f. cavities to cope with the high intensity beam anticipated.

During a joint development session the continuous transfer extraction (supplying the beam for SPS fixed-target operation) was set up for 14 GeV/c. The general behaviour of the beam, observed up to an intensity of 1.8 $\times 10^{13}$ protons per pulse, was distinctly better than at the former momentum of 10 GeV/c; the loss of a few per cent just before extraction completely disappeared. The beam also behaved better on the injection field plateau at 14 GeV/c in the SPS, and the overall result was a gain of some 10% in transmission between the PS and the SPS. The new transfer momentum was therefore adopted for normal operation. However, no systematic study had yet been carried out on the transverse emittances and radial and longitudinal instabilities of this beam, particularly their dependence upon intensity.

New equipment was installed during the long shutdown at the beginning of the year for beam control during acceleration with the standard r.f. harmonic number 20. After setting up and adjustment, acceleration with this harmonic number became operational over the intensity range from 10^{10} to 4 $\times 10^{13}$ protons per pulse, and for any number of bunches from one to twenty. Two of the 200 MHz r.f. cavities were also fitted with tuning pistons so that they could operate on two different frequencies from one cycle to another. This allowed them to be used for the controlled longitudinal expansion required for the antiproton production beam as well as for the recapture at 200 MHz of beam destined for the SPS.

For the single-bunch antiproton beam accelerated with a harmonic number of 6 and sent to the SPS for collider operation, the influence of the orbit deformation required for extraction at 26 GeV/c upon reproducibility of the longitudinal compression down to

4 ns before extraction was confirmed. Modifications made during the long shutdown allowed the rise time of the orbit deformation to be extended, and the effect of this was to produce excellent stability in energy and phase during the compression. After modifications to the vacuum chamber in the extraction region, the efficiency of extraction of this single-bunch beam, with a nominal $\Delta p/p$ of $\pm 3 \times 10^{-3}$, reached almost 100%. Nevertheless, studies continued on the reduction of the parameter α_p (momentum compaction factor) in the extraction region, in order to be able in the future to extract bunches with a greater $\Delta p/p$, thereby using a larger fraction of the AA antiproton stack. This modification of α_p, carried out with the aid of additional quadrupoles, was tried first with a proton beam and subsequently with antiproton extraction. The results were very encouraging, and enabled plans to be made for installation of the elements necessary for the extraction of beams with bigger $\Delta p/p$ during the next long shutdown.

Computer Control

The year of 1984 saw the successful completion of the PS Controls Conversion Project, begun in 1978. This project embraced the complete conversion of the PS controls to a fully computerized system, using an integrated network of NORD computers, a homogeneous CAMAC interface and a number of versatile general-purpose consoles in the central Main Control Room (MCR). The planned conversion was duly accomplished in 1984, despite the superimposition at an intermediate stage of the Antiproton Accumulator (AA) and numerous significant elaborations demanded by the growing needs of the experimental physics programme. The development of the PS accelerator complex brought further extensions, and work continued on conversion of the PS r.f. system (not included in the original project), controls of the LEP Preinjector and preparations for the Antiproton Collector.

Early in the year, the third and last instalment of the original conversion project was successfully commissioned. This comprised the controls and instrumentation of the various beam extraction and transfer systems and, owing to the high degree of versatility required and the arrival of antiprotons, included an intricate timing system. The system was ready according to plan, but, since the scheduled commissioning time was lost owing to delays in putting the modified access control system into service (see 'Operation' above), each of the many modes of operation had to be commissioned whilst actually being used for the experimental programme. This made the whole process much more difficult, and led to some delays in optimizing operations.

The PS radio frequency systems, which had earlier for the most part been excluded from computer control, had grown considerably over the intervening years. Not only had a new system (200 MHz cavities) been added, but several different harmonics of the accelerating frequency were being used for 'beam gymnastics' operations. It was therefore decided that the r.f. systems should be fully integrated with the other PS computerized controls, yielding a project of the same dimension as the other three major instalments. Some small parts were commissioned during 1984, but completion of the whole conversion was not planned until early in 1985. A local mobile console, fully software-compatible with the main operator consoles, was installed adjacent to the low-level electronics of the r.f. systems. A further step towards integration of controls throughout the accelerator complex was taken before the end of the year, with the commissioning of a dedicated data link between the MCR consoles and the Linac/LEAR controls system which had, for historical reasons, hitherto remained completely independent.

The controls for the LEP Preinjector (comprising two linear accelerators and a storage ring) were designed as an extension of the PS system, but adapted in several ways to meet the special needs of this project. Two significant new developments were being included. Firstly, there was the use of a much more powerful local crate controller (SMACC) based on the MC 68000 microprocessor, which had been adopted as a CERN standard. This 'local intelligence' device allowed a certain extent of stand-alone operation for some groups of equipment, such as klystrons and associated modulators, where this facility would be useful for engineering purposes. Secondly, but closely related, was the adaptation of application software structures, not only to take into account the extended use of the SMACC but also to incorporate a number of improvements suggested by experience with the new PS controls since 1980. These aimed essentially at greater reliability and ease of operation and improved productivity in the field of applications software.

The intended use of the SMACC also placed a new emphasis on the importance of user-friendly local interaction for engineering purposes at several levels

Figure 13 — PS Division and their guests wining and dining on the twenty-fifth anniversary of PS operation. (CERN-337.11.1984)

of the process interface. The advent of the Apple personal computer 'MacIntosh' rapidly brought about the extensive use of that powerful and versatile unit in this rôle. At the end of the year a first demonstration was made of the MacIntosh controlling one CAMAC crate, using the NODAL interpreter language, through a dedicated serial driver allowing ultimately the addressing of up to 62 crates. Also for local interaction, a graphics and alphanumeric software package for NODAL was made up suitable for use in the ND front-end computers and on the TMS 9900 and 99000 auxiliary crate controllers, as well as in the MacIntosh. Two main operator consoles were under construction, for local and MCR control. A prototype SMACC module was under test with the systems software, comprising an operating system, a communications package for data exchange between SMACC and the front-end computer and language support for NODAL and P+. The adaptations required in the applications software structures were in progress. Layout of the process interface and definition of the timing system were well under way.

The LEP Preinjector

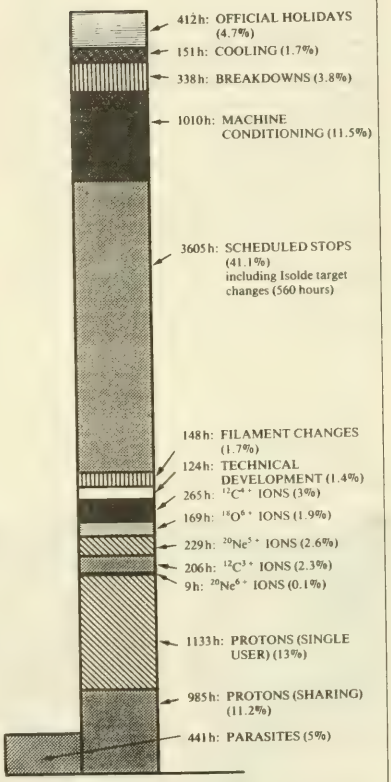
Since it constitutes an important part of the LEP project, this subject is covered in the LEP chapter of this report. However, PS Division is responsible for the construction of the two linear accelerators, the accumulator (EPA) and the transfer lines which will supply electrons and positrons for initial acceleration in the PS prior to their transfer to the SPS and finally to LEP. Progress made this year is compatible with the targets of first linac beam tests in 1985 and completion of the EPA by mid-1986. Necessary modifications to the PS itself are mentioned in other sections here ('Main Proton Synchrotron' and 'Computer Control' especially).

Safety and Services

Considerable emphasis continued to be placed on matters of safety and, in particular, in ensuring that individuals should be aware of their responsibilities and the resources available to provide assistance and advice. The Safety Committee met seven times. It discussed, among other topics, safety education, general information on CERN safety organs and problems, results of exercises (e.g. evacuation of buildings) and the analyses of various accidents and incidents.

Work began on the renovation of the PS access control system. Some parts were as old as the PS itself, and their future reliability could not be guaranteed. It was intended that replacement material should, as far as possible, be standardized with that to be used by LEP and the modernized SPS. Computer-driven displays to help the operating crews in interpreting information were being introduced.

Figure 14—The allocation of SC machine time in 1984 (24 hours per day).



Over the previous few years a large amount of administrative work had been automated, in particular inventory control, preparation of budgets, overtime and service contracts, travel records, etc. This enabled the Division to manage a considerable increase in activity without additional staff. In 1984 a NOTIS office automation system, with a link to the Administration Departments and DG Services for text and message transfer, was installed. The use of text processing equipment for the preparation of scientific reports and internal working documents became general.

SYNCHRO-CYCLOTRON

Operation and the Experimental Programme

According to plan, the time devoted to experimental physics was again reduced in 1984, in order to provide money and manpower for the ISOLDE 3 project (see below, and page 97 of the 1983 Annual Report). The proportion of the available time given to acceleration of light ions rose from 18% in 1983 to 30% this year, leaving 70% for proton acceleration. Main users were again ISOLDE, Muon Spin Rotation (μSR) and the experiments employing beams of light ions. Operating statistics are shown in Fig. 14 and the experimental layout as it was at the end of the year in Fig. 15.

During the months of January, February and March the SC ran in the light-ion mode. This was a highly satisfactory period for physics, since for the first time the full range of ions was on offer—$^{20}Ne^{5+}$, $^{20}Ne^{6+}$, $^{18}O^{6+}$, $^{12}C^{4+}$ and $^{12}C^{3+}$ were all used at one time or another. This had been made possible by the installation of a multi-frequency transmission line between the Dee (accelerating electrode) and the Rotco (rotating capacitor governing the radio frequency). A complete catalogue of SC beams is shown in table 1.

In the scheduled April shutdown, three important maintenance jobs were tackled. The main bearings of the Rotco in use (No. 2) were replaced; it was found that one of them had split in two, accounting for the unusually high noise level which had been noted. An r.f. filter in the centre of the machine was repaired, and the primary water circuits of three heat exchangers were replaced. Whilst carrying out the latter operation, it was also observed that the water system in general was heavily corroded—hardly surprising, since much of it was nearly thirty years old. The SC

Figure 15 — Layout of the SC experimental areas at the end of 1984.

Proton Hall

μSR experiments are carried out in the "C" zone, sharing the beam with similar experiments in the Neutron Hall. This is also the zone where the experiments are housed which use beams of light ions. The remainder of this area has been set aside for ISOLDE 3.

Neutron Hall

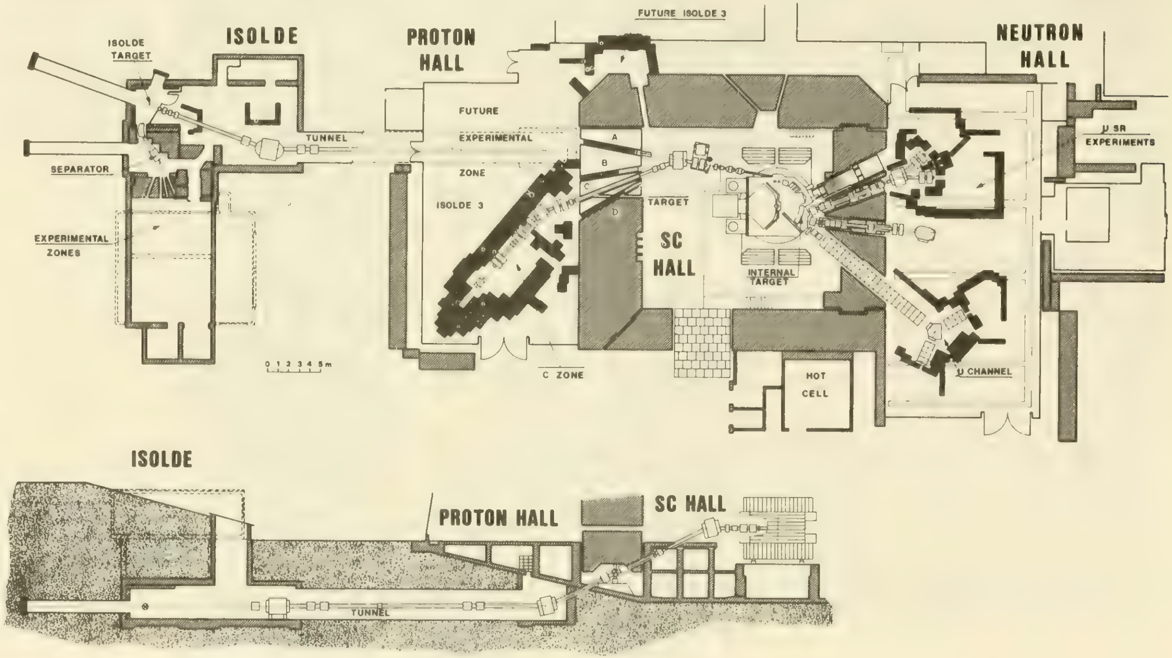
μSR experiments are carried out in the zone indicated, and the two arms of the μ channel are used for parasitic tests employing low-intensity π^- and μ^- beams.

SC Hall

This is where the pion production target in the extracted proton beam is housed. Irradiations are often carried out in the extracted beam, using both protons and ions.

Underground Zone

This is the on-line isotope separator facility, ISOLDE. Irradiations are also occasionally made at the centre of the tunnel.



Catalogue of SC beams

Particle	Energy (MeV/N)	Extracted intensity (Part/Sec)	Frequency range (MHz)
PROTON	602	$> 3 \times 10^{13}$	30.1 — 16.8
$^{3}He^{++}$	303	$> 3 \times 10^{12}$	20.3 — 13.9
$^{3}He^{+}$	85	$> 10^{13}$	10.1 — 8.5
$^{12}C^{4+}$	85	$> 10^{12}$	10.1 — 8.5
$^{15}N^{5+}$	85	$> 10^{11}$	10.1 — 8.5
$^{18}O^{6+}$	85	$\sim 3 \times 10^{11}$	10.1 — 8.5
$^{16}O^{6+}$	107	5×10^{9}	11.6 — 9.4
$^{14}N^{5+}$	97	$\sim 10^{9}$	10.8 — 9.0
$^{20}Ne^{7+}$	94	$\sim 5 \times 10^{9}$	10.6 — 8.9
$^{20}Ne^{6+}$	70	$\sim 3 \times 10^{10}$	9.1 — 7.7
$^{20}Ne^{5+}$	49	$\sim 3 \times 10^{11}$	7.6 — 6.6
$^{12}C^{3+}$	49	$> 10^{12}$	7.6 — 6.6

then ran with protons through the months of May, June and July.

August and September were devoted to preliminary building modifications for the ISOLDE 3 project. Operation began again in October, initially with rather frequent r.f. sparkovers, but after two weeks things settled down, and the standard performance of 4 μA beam intensity with 20 kV r.f. voltage and a 1 in 2 duty cycle could be maintained.

The machine continued to run smoothly throughout November and December, main users being ISOLDE and μSR together with the last allocated irradiation of a simulated meteorite for Cologne. During the whole year both muon channel beam lines were frequently used by experimenters in a parasitic mode. One experiment, by EF Division, employing a liquid argon bubble chamber, reached its conclusion and was dismantled.

The μSR programme continued to study the positive muon in various solid and liquid environments. Traditional studies of metals at low temperatures were complemented by measurements at high pressures where changes in the electronic structure of ferromagnetic materials and semi-metals can be probed by the muon. Another field in which interesting results were obtained was the study of molecular dynamics in plastic crystals. These are wax-like substances with the molecules rotating extremely fast around fixed lattice centres. By tagging muons to these molecules it was possible to determine different slowed-down rotations which take place at low temperature just above the point at which all motion ceases.

Development

Extending the life of the ion source filament, in order to reduce SC down-time, had been a constant preoccupation. The concept of a carrier gas was tried out in connection with the acceleration of $^{18}O^{6+}$ ions. This uses the admixture of a gas of higher molecular weight—usually one of the inert gases—to stabilize the arc. Precise proportions are important, and a sophisticated mixer had to be designed and built. Results were quite successful; average filament life was extended from 6 to 10 hours.

ISOLDE requested that beam intensity for $^{3}He^{++}$ acceleration should be increased by a factor of two or three. With these ions, current r.f. system limitations only permitted a voltage of 20 kV with a 1:3 duty cycle or 17 kV with 1:2. What was being called for implied running at 20 kV with a 1:1 duty cycle, so a detailed study was made of each component of the r.f. system (generator, transmission line, Rotco). The weak links were found to be the parasite absorption filter in the generator and the (8) ceramic blocking capacitors in the Rotco. New capacitors were ordered for a redesigned filter capable of handling higher power. Better cooling had already been provided for the blocking capacitors in Rotco No. 1, and as an

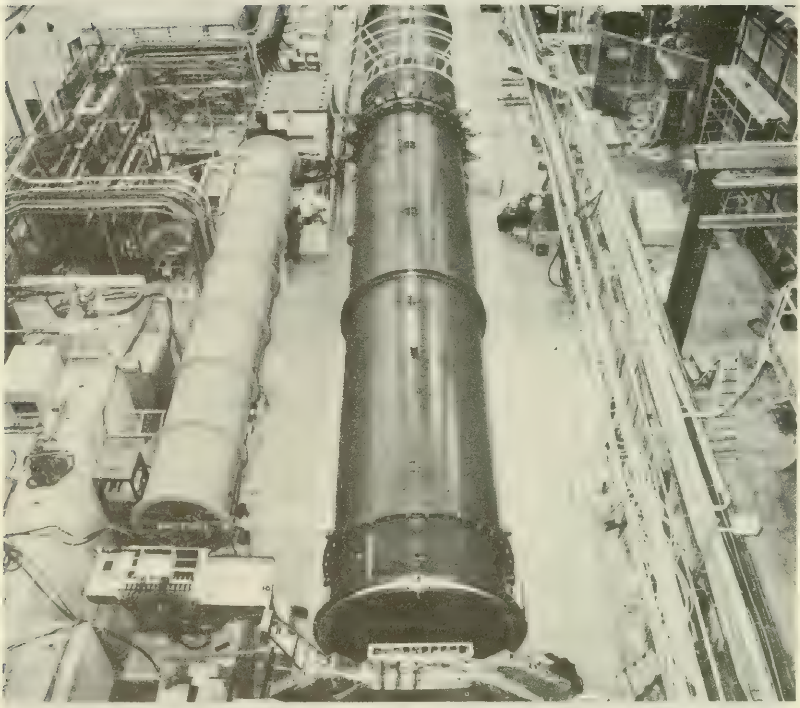
Figure 16—In preparation for the installation of the new on-line isotope separator, ISOLDE 3, passages for cables, etc. had to be provided between the SC and the Proton Hall. This shows the drilling of a hole 55 cm in diameter through some six metres of reinforced concrete shielding. (CERN–415.6.1984)

added protection it was planned to increase the impedance of the series compensating coils, thereby reducing the current flow. This had been shown to work for the accelerating frequencies used for C and Ne ions, but it was not possible to get the higher frequency range required for $^3He^{++}$ without modifying the transmission line linking the Dee to the Rotco. A prototype line was successfully tested, and the final version was under construction.

It appeared that future SC activity would concentrate increasingly on proton and $^3He^{++}$ acceleration. With this in mind, a second r.f. generator capable of producing 20 kV at a 100% duty cycle was constructed and partially tested. Its behaviour at high power and $^3He^{++}$ frequencies had yet to be determined.

Construction of the second on-line isotope separator (ISOLDE 3—mentioned in the Annual Report for 1983, page 97) began. The production target was to be located in the SC machine hall, and the separated isotopes would be collected in the proton room. Most of the building alterations were completed during the shutdown in August and September. Various Institutes, Universities, etc., who were members of the ISOLDE collaboration, assisted with the project; design of the ion source assembly, accelerating section lenses, bending magnets and shielding were completed and manufacture begun. An industrial robot, similar to the one already in use at ISOLDE 2 for target handling, was on order.

Super Proton Synchrotron Division



The vacuum tank of the experiment NA31 which stretches over 110 m length in the hall EHN1 and provides a volume of 400 m³ at a vacuum of 0.1 mbar
(CERN-288.06.84)

Super Proton Synchrotron Division

Introduction

Further progress has been made in the performance of the SPS as a proton-antiproton collider and for the acceleration of protons for fixed-target physics.

As a result of the upgrading programme for the cooling water system and the main power supplies during the winter shutdown, the collider energy has been increased from 273 to 315 GeV per beam. This increase in energy, the further squeezing of the insertions to lower beta values, some increase in the proton intensity per bunch and the improved lifetime of the antiproton beam, were the main factors which contributed to the improved collider performance. The best value of the initial luminosity of coasts has increased from 1.6×10^{29} cm^{-2} s^{-1} in 1983 to 3.6×10^{29} cm^{-2} s^{-1} this year. The total integrated luminosity was 395 nb^{-1}, which represents an increase by a factor of 2.6 as compared to the result of the previous year during a period of comparable duration.

The operation for fixed-target physics was smooth and the SPS proved very reliable. In April the momentum of the injected protons was raised from 10 GeV/c to 14 GeV/c, the maximum which can be handled by the 5-turn extraction system of the CPS. The smaller transverse beam size at 14 GeV/c led to an improvement of the beam transmission between the moment of injection until after acceleration to 450 GeV, from a previous 84% to a new best value of 94%. Furthermore, the threshold for collective beam instabilities is higher at 14 GeV/c than at 10 GeV/c enabling the accelerated beam intensity to be increased from a previous maximum of 2.7×10^{13} to a new record value of 3.4×10^{13} protons per pulse, averaged over a 15 minute period of operation.

The SPS Collider

Machine Studies and Collider Performance

In 1984 the period of collider operation occurred in the autumn. A few machine development sessions earlier in the year were devoted to its preparation, mainly to test the functioning of the machine at the increased energy of 315 GeV and to commission the reduction of the minimum values of the betatron functions at the experiments to $\beta_H^* \times \beta_V^* = 1$ m $\times$ 0.5 m as compared to last year's values of 1.3 m $\times$ 0.65 m. The smaller beam size resulting from the increased energy and the lower beta values at the interaction points result in an increase of the luminosity by 50%.

In this configuration the betatron functions reach maxima of 2500 m in the horizontal plane and 640 m in the vertical plane. Even with the closed orbit excursions corrected to within a few millimetres, the acceptance of the machine was found to be marginal in certain parts of the insertions. In order to provide enough aperture, the vacuum chamber in a quadrupole was replaced by an enlarged one and an MBA dipole was replaced by an MBB dipole which has a larger gap height in each of the two insertions. With these modifications the background rates in the experiments were similar to the values of last year.

Four additional quadrupoles, which had been installed during the winter shutdown, were used to measure accurately the beating of the betatron functions in the normal part of the lattice. This proved essential for a good matching of the insertions, and greatly helped the tuning of the machine. The horizontal-vertical betatron coupling was enhanced due to the lower values of β^*, but could be corrected with skew quadrupoles. The increased chromaticity was satisfactorily corrected with the existing four families of sextupoles. The residual high order aberrations are small enough in a well-matched machine to pose no operational problems. However, the third integer stop bands were widened and this reduces the space available in the tune diagram.

The damper is now used on an operational basis to reduce the effect of the residual betatron injection oscillations for each of the antiproton bunches as well as for the protons. As a consequence the emittances are better preserved and the losses during the flat bottom and early acceleration are reduced. The overall transmission from injection up to coasting energy varies between 85% and 92%.

The lifetime of the antiproton beam, which was typically 40 h in 1983 has been increased to over 100 h after a few hours of storage due to a lower noise level in the antiproton acceleration system. The lifetime of the proton beam, which is dominated by intrabeam scattering, remains unchanged. Minute excitations of the horizontal betatron oscillations were found to be caused by high harmonics of the switching pulses from the main power supplies, which are able to propagate along the magnet chain. Their amplitude has been reduced by better filtering, and lower growth rates of the horizontal emittances have been recorded since then. As a result of the reduced loss rate of anti-

protons, and of the lower growth rate of the emittances, the luminosity lifetime, which was on average 16 h last year, has been increased to over 24 h. This has allowed the AA to accumulate antiprotons for a longer time between transfers, and has therefore contributed to an increased peak luminosity.

In order to make use of the increased antiproton intensity expected from ACOL, it will be necessary to store 6 bunches of each beam in the collider. This results in twice the tune spread with respect to the present situation and it is already known that the lifetime will then be unacceptably low. In order to reduce the tune spread to a tolerable level, an electrostatic separation scheme has been proposed and prototype hardware has been installed and was tested in the 1984 collider run. Two orthogonal pairs of electrostatic separators, situated in LSS4 and LSS5, provide sufficient deflection to separate the three bunches of each beam in all collision points except in the two experimental areas.

Experiments have shown that the scheme works as expected. The beam centres were separated by a distance of three times the beam diameter at the unwanted crossings, whereas the residual separation in LSS4 and LSS5 was carefully minimized. The beam lifetime was at least as good as that obtained without separation and the results prove the feasibility of a beam separation scheme in a proton-antiproton collider. An experiment in which one beam moved slowly through the other has shown that the lifetime of the antiproton beam is insensitive to the amount of partial separation.

The operating energy of the collider is limited by the average power dissipation tolerable in the main magnets. Through increasing the flow rate of the cooling water, it was possible to raise the operating energy from 273 GeV to 315 GeV. To reach higher energies under the present conditions, it is necessary to operate the collider in a pulsed mode. In this mode of operation the beam is decelerated after a plateau at the maximum energy and held for some time at low energy in order not to exceed the allowed average dissipation, whereafter the beam is accelerated again.

A first step towards such a 'pulsed collider' was made in 1984 using protons only. A cycle of 21.6 s duration with a flat top of 3 s at 450 GeV and with a flat bottom of about 10 s at 100 GeV has been set up. A dense proton bunch stored with this cycle had a lifetime of 2 to 3 hours. It is limited by the diffusion rate in the RF buckets which is larger than in normal operation. During storage at fixed energy the RF bucket remains stationary whereas in pulsed mode it continuously shifts from stationary to accelerating or decelerating and vice versa. This is likely to generate additional noise and enhance particle diffusion across the separatrix.

In order to ensure a reasonable lifetime for the antiprotons which suffer from the space-charge effect of the strong counter-rotating proton beam, it is necessary to limit the excursion of the tunes over the whole cycle to ± 0.005. This is sufficient to avoid the resonances of order 10 or less which are known to reduce considerably the lifetime. Although this tune excursion is more than one order of magnitude larger than what is achieved in a coast at fixed energy, it is an order of magnitude smaller than in a normal proton accelerating cycle for fixed-target physics.

To cope with this challenging demand new techniques have been developed. Firstly, an automatic tune measurement system is used which gives a small kick to the beam every 60 ms and then performs a Fast Fourier Transform of the oscillating signals to determine the tune. The results are sent directly by programme to the computer which generates the references for the main quadrupole power supplies in order to correct the tunes in the desired direction. Thereafter, the more precise continuous Q-measurement system is used to further minimize the errors. This system excites the beam continuously through a phase-locked

Table 1 — Best collider performances in 1983 and 1984

	1983	*1984*
Momentum (GeV/c)	273	315
Proton intensity	$3 \times 14 \times 10^{10}$	$3 \times 16 \times 10^{10}$
Antiproton intensity	$3 \times 1.5 \times 10^{10}$	$3 \times 2 \times 10^{10}$
$E_H \approx E_V$ for protons (π mm mrad)	6×10^{-2}	7×10^{-2}
$E_H \approx E_V$ for antiprotons (π mm mrad)	5×10^{-2}	3.5×10^{-2}
$\beta_H^* \times \beta_V^*$ (m × m)	1.3×0.65	1×0.5
Initial luminosity ($cm^{-2} s^{-1}$)	1.6×10^{29}	3.6×10^{29}
Luminosity lifetime[1)] (h)	16	24
Proton intensity lifetime[1)] (h)	60	60
Antiproton intensity lifetime[1)] (h)	40	100
Emittance growth rate[1)] (π mm mrad h^{-1})	3×10^{-3}	1×10^{-3}
Beam-beam tune shift per crossing point	0.004	0.004
Background rates at the experiments		
– from protons (%)	2 to 5	2 to 5
– from antiprotons (%)	< 1	< 1

1) Typical value for a coast some hours after injection.

loop and measures the frequency of the loop signal to determine the tune in real time. In this way the required accuracy in the tune settings could be reached. It remains now to inject antiprotons in this mode to test whether an antiproton lifetime of at least a few hours can also be achieved.

SPS Collider Operation

This year, like in 1983, 13 weeks were devoted to collider physics operation. A week of machine development, just before the scheduled 10-day stop for the installation of the experiments in ECX4 and 5, provided a good preparation for proton-antiproton operation and permitted an efficient start-up of the SPS in the collider mode for physics at 315 GeV and with the low beta insertions further squeezed to $\beta^*_H \times \beta^*_V = 1\ \mathrm{m} \times 0.5\ \mathrm{m}$. At the start of the period, the initial luminosities were around $1 \times 10^{29}\ \mathrm{cm^{-2}\ s^{-1}}$ and

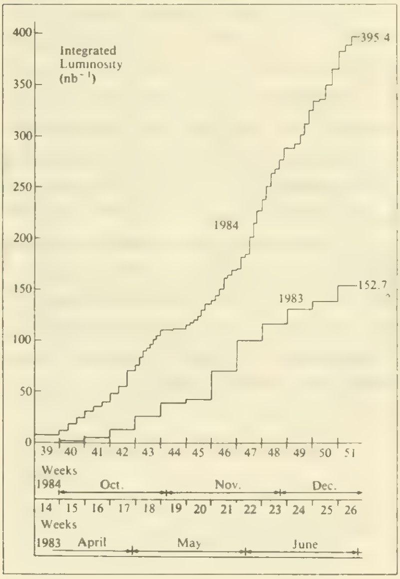


Figure 1 — Integrated luminosities in 1983 and 1984.

it took another two weeks to reach values comparable to the previous record of $1.6 \times 10^{29}\ \mathrm{cm^{-2}\ s^{-1}}$. Subsequently, after further improvements mainly in the antiproton transfer efficiency from the AA via the PS to the SPS in conjunction with record stack intensities in the AA, the initial luminosity has risen to a maximum value of $3.65 \times 10^{29}\ \mathrm{cm^{-2}\ s^{-1}}$.

The SPS proved to be very reliable during the first half of the period and only 5 out of 33 coasts were lost due to technical faults. The second half of the period was less fortunate and 20 out of 44 coasts were lost due to various, mostly minor and unrelated faults. Nevertheless, the total integrated luminosity increased by a factor 2.6 as compared to the result of the previous year. This was the result of higher initial luminosities, because of the higher beam energy and lower beta values at the insertions, as well as of a 15% increase of the proton intensity per bunch, the improved luminosity lifetime and the availability of higher intensities of the AA stack.

The operation of the SPS has become easier this year by the consolidation of a number of facilities which were still in the prototype stage last year. The on-line storage on the CERN main frame computers of the data concerning each particular shot greatly improves the diagnosis of imperfections in the injection chain and provides a record for analysis of the history of the coast.

The sequencer continues to be the basic means of putting all the equipment in the SPS into the correct state and checking that this state is maintained. As more and more conditions for good transfers are established the sequences are updated.

The multiple Q-measurements have been very successful and have reduced the beam time needed for the optimisation of the machine parameters through the acceleration from as much as 8 hours to about as many minutes. Its advantage for operation lies in the ability to take a consistent set of data relevant to one cycle and analyse it quickly and precisely. Once the operator accepts this data, the necessary changes to the main power supply currents are requested at the touch of the button.

Apart from the routine maintenance and generation of applications software to keep pace with the commitments of the SPS operation programme, two interesting software projects have been completed.

The first project has been the implementation of a general purpose plotting package for data presentation and operator interaction on the consoles. This is the first large high-level, general-purpose package that

Table 2—SPS performance for proton-antiproton physics

	1982	1983	1984
Total scheduled hours of operation	1750	2064	2136
Total hours with coasting beams	748	889	1065
Number of physics stores	56	72	77
Peak initial luminosity ($cm^{-2} s^{-1}$)	5.1×10^{28}	1.68×10^{29}	3.65×10^{29}
Integrated luminosity (nb^{-1})	28	153	395

has been produced at the SPS. Because of the very attractive gains that can be made in effort and end product utility this package has immediately become heavily used.

The second project developed on the general data facility computer is a resident high-level task which periodically collects and makes available from a centralized source a set of initially distributed data. This method was applied to the orbit measurement data. Again this project gave immediate returns with a permanent display of the orbit becoming an important operational tool which, together with the above-mentioned plotting package and the multiple data collecting facility, led to a rapid development of a measurement of the chromaticity throughout the machine cycle.

Technical Developments of the Collider

During the winter shutdown of early 1984, a great effort was made to increase the flow rate of the cooling water for the SPS main magnets by more than 30% to raise the energy for collider operation from 273 to 315 GeV per beam. To this end a booster pump was added at the level of the machine tunnel in each sextant. In parallel with these modifications, the cooling circuits for the main power supplies had to be upgraded. Therefore, two pumps in BA2 were replaced by larger ones and some other pumps were relocated.

Similarly, the water circuits inside all main power supplies were improved, including the replacement of the hydraulic manifolds on the chokes of the electrical filters by units of an improved design. Also the busbars in the power supply cubicles were reinforced and additional ventilation installed. In addition, the power supplies of the low beta insertions have been upgraded for operation at 315 GeV. This involved new current control loops to compensate for the saturation effect of the quadrupoles, recalibration of the DCCT's and improvements to busbars and connections to handle the higher currents.

The horizontal and vertical Schottky signals are essential for the measurement of the betatron tunes during a coast. The electrodes of the horizontal Schottky beam monitor are now suspended by narrow strips to insulate them from mechanical vibrations. The natural resonant frequency of this system, about 1 Hz, results in a strong rejection of vibration frequencies around the betatron lines. The basic noise level, which has been reduced by 20 dB, is now limited by electronic noise and similar to that of the vertical signal which has always given good results.

However, unwanted interference lines comparable in amplitude to the betatron lines still exist and make identification of the peak frequency difficult. Using the RF accelerating cavity as a highly sensitive transverse monitor by filtering out signals in the second higher order passband at 460 MHz, another completely independent measurement of the 'Schottky' bands has been obtained and shown to be identical to that obtained by the more standard method. This strongly indicates that the observed structure is truly a beam response to an excitation and a search is being conducted to identify possible sources. The most likely candidates are high harmonics of the main power supply switching pulses propagating through the SPS magnet chain, which acts as a wide passband delay line.

The regulation circuits for the four RF cavities have been completely redesigned around low-noise 10.7 MHz voltage controlled oscillators. The phase noise levels observed on all cavities have been reduced by at least 20 dB. This reduction is reflected in the increased lifetime of the antiprotons as observed during collider operation, the lifetime being at least twice that observed last year and seemingly limited by other than RF causes.

In preparation for future collider operation with high luminosities a scheme has been worked out to separate the beams at all crossing points except those from LSS4 to LSS5. For a first, reduced version of this scheme which can only separate three proton bunches from three antiproton bunches, the four electrostatic deflectors originally installed for luminosity measurements, have been redeployed. The proton and antiproton orbits are horizontally separated by an

Figure 2 — One of the two UA1 hadron absorber walls installed in the experimental area ECX5. These walls are built up from 80 cm thick cast iron blocks and are about 11 m high and 8 m wide, each containing about 500 tons of shielding. (CERN-013.03.84)

orthogonal pair of deflectors downstream of the collision point of LSS5 and recombined by another orthogonal pair upstream of the collision point in LSS4. This system has been used successfully this year for separation experiments.

It is necessary to upgrade this system to make it operational for the separation of six bunches of protons from six bunches of antiprotons. For this purpose, four additional deflector units must be built and new, more stable high voltage generators are needed. All major new components, such as vacuum tanks, titanium electrodes of 3 m length and their motorized supports as well as the high voltage generators have been ordered.

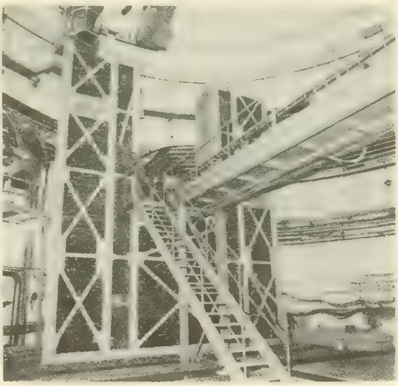
New facilities for monitoring the intensity of the protons and the antiprotons bave been commissioned. The implementation of a pair of directional couplers for the measurement of the beam intensity of each bunch of protons and antiprotons allows, due to their high directivity of 35 db, a good separation of the signals from bunches with down to 10^9 antiprotons per bunch from those of bunches with up to 1.6×10^{11} protons per bunch. Through the acquisition at injection of the intensities of each proton and antiproton bunch over each of 1000 consecutive turns, the injection losses during the first few turns are easily separated from the RF capture losses which occur during the first few milliseconds. A second system connected to the same directional couplers measures the intensity of each bunch every 30 ms during 30 seconds and gives the beam loss at any time during the acceleration cycle between injection at 26 GeV and beginning of coast at 315 GeV. A third system monitors the intensity of each bunch every 15 seconds during the whole duration of the coast.

The rapid acquisition and treatment of the large amount of data in each of the first two systems is done in local microprocessors. The parameter and data transmission between these microprocessors and the SPS control system uses for the first time the concept of a fully decentralized data module subroutine which has moved from a control computer into the local microprocessors. A software protocol in the computer dispatches the data module properties via the MPX transmission lines to the corresponding microprocessor.

An aluminium-beryllium vacuum chamber assembly has been made and tested for the UA1 experiment. This new assembly will be installed in 1985, in replacement of the present, much less transparent chambers of stainless steel. The new system has a central part of beryllium with a length of 0.8 m and inner diameter of only 50 mm. The rest of the 12 m long system consists of a beam channel in which all tubes, flanges and bellows are made of aluminium. The system is joined to the SPS ring via aluminium-stainless steel transitions. During tests the required pressure of about 10^{-10} mbar was achieved after pumping and a bakeout.

The Proton-Antiproton Experimental Areas

As part of the improvements for the UA1 experiment, the SPS Division designed and coordinated the installation of a new layout for the forward/backward muon chambers and hadron absorber walls in the experimental area ECX5. These absorber walls are 11 m high and 8 m wide and consist of about 1'000 ton of iron shielding which became available as a result of the recent upgrading of the SPS West Experimental Area and the closure of the ISR. The forward muon chambers, formerly on the mobile chariot, are now installed between the absorber wall and the wall of ECX5. Many cables, water pipes and the gas distribution had to be redeployed or modified and new fixed and mobile platforms provided to accommodate the new layout. A new mechanical system to open and close the compensating magnets (CALCOM's) also had to be designed and built. The muon identification was further improved by adding mobile iron shielding



above the muon chambers underneath the UA1 detector mounted on its platform.

Additional iron shielding was provided in LSS4 and LSS5 to protect the UA1 and UA2 experiments from background originating in the quadrupoles of the low beta insertions.

Three special "Roman Pots" were constructed and installed for the new small-angle scattering experiment of the UA4 collaboration, which is scheduled to run in June 1985.

The SPS Accelerator

Machine Studies and Accelerator Performance

Until the spring of 1984, the beam was injected into the SPS at 10 GeV/c in two successive batches, each sliced over five turns in the CPS by the continuous transfer scheme. The accelerated intensity was limited to about 2.8×10^{13} protons per pulse by a lack of machine acceptance in the transverse planes, collective instabilities and too large tune spreads which caused the tails of the beam distribution to be lost on non-linear resonances. These effects proved more difficult to correct than expected and the situation became even worse when attempts were made to inject higher intensities using three PS batches sliced over three turns. In this case the emittances are larger and the ratio of the peak intensity to the average intensity around the ring also increases.

It was therefore decided to try injection at a momentum of 14 GeV/c, while remaining with two batches sliced over five turns. The beam size as well as all transverse space-charge effects and instabilities are reduced at this energy. Until recently, this possibility was not attractive because injecting closer to the SPS transition momentum of 21.8 GeV/c would have considerably increased the beam-loading effects in the SPS accelerating cavities, and these effects were already a limitation at 10 GeV/c. However, an RF feedback system was designed to reduce the effective coupling impedance of the cavities. This greatly improved the behaviour of the beam in the longitudinal plane and it was felt possible to control these longitudinal effects up to a momentum of 14 GeV/c. Injection at this momentum proved indeed to be very successful. Although the matching in the longitudinal plane became more difficult, as was expected, all the transverse problems practically disappeared, allowing a perfect transmission of the beam from injection to transition energy where a few percent of losses remained. A peak intensity of 3.4×10^{13} was accelerated, with an overall transmission efficiency of up to 94%.

Accelerator Operation

The January-February shutdown was followed by a scheduled technical run of the SPS during 3 weeks. In spite of the loss of 10 days due to 'critical days', a contractually required reduction in the electricity consumption, the operation of the SPS in the collider mode at 315 GeV could be successfully tested and the machine was then prepared for fixed-target physics.

The fixed-target operation started with moderate intensities to restart the physics programme and in early April, after a machine development session, the injection momentum was permanently raised from 10 to 14 GeV/c. The transmission efficiency was immediately found to have improved up to 94% with 2.5×10^{13} protons per pulse accelerated to 450 GeV compared to at most 84% efficiency with injection at 10 GeV/c.

In periods two and three with the experiments fully operational, the intensity was gradually increased until a peak intensity of 3.4×10^{13} protons per pulse was recorded for the highest intensity over any 15 minute period of operation.

Table 3 — SPS Operation for fixed target physics

	1979	*1980**	*1981***	*1982*	*1983****	*1984*
Total scheduled hours of operation	5346	3106	2764	4080	3271	3699
Total scheduled hours for physics	4458	2497	1913	3176	2664	2757
Efficiency for physics*** (%)	79	88	75	76	70	82
Peak intensity ($\times 10^{13}$)	2.4	2.6	2.6	2.8	2.8	3.4
Total number of protons delivered to targets ($\times 10^{18}$)	17.7	14.1	5.8	14.1	9.75	13.9
Average number of protons/scheduled hour of physics ($\times 10^{13}$)	397	564	303	444	366	504
Typical cycle times (s)	9.6 10.8	10.8	12	10.8 12	12	12 14.4

* up to 16th June
** from 11th June to 4th November
*** the 70% efficiency for physics in 1983 includes the effect of 9 days of EDF power reduction. Without the latter, the efficiency for physics would have been 77%.

Figure 3 — Assembly of the new beam dump for the TT60 beam transfer line. The water-cooled core consisting of carbon and copper is embedded in a 20 ton cast iron shield. The dump can absorb fast and slow bursts of 3 × 10^{13} protons at 450 GeV. (CERN-438.11.83)

The SPS ran for most of the year with a repetition time of 14.4 s. which allows a flat top at 450 GeV of 2.8 s. and thus a duty cycle of the counter experiments in the North and West Areas of about 20%. The increased intensity performance compensated the neutrino physics for the slower repetition time.

The overall efficiency of operation, the ratio of actual beam time to scheduled beam time, was 82%. The worst period was in the summer when the electrostatic septa of the extraction channels were found to suffer from the high extracted beam intensity. The accelerated beam intensity was thereupon reduced to 3.1×10^{13} protons per pulse to reduce the risk of failure of these septa.

Technical Developments of the Accelerator

In 1983 the protons were for the first time extracted simultaneously at 450 GeV to both the North and West experimental areas. As predicted, this resulted in an increase of the extraction losses in LSS6 at the electrostatic septa which are the first elements of the extraction channels. The extraction losses increased even further because of the higher accelerated intensities. This led to a progressive deterioration in the performance of the extraction system which became severely limited by thermal deformation of the support of the electrostatic wire septum due to radiation heating. This deformation causes an increase in the effective septum thickness which in turn increases again the extraction losses.

An improvement project had therefore been launched with the aim to replace the stainless steel support of the wires by a support made of invar. At the same time the diameter of the wires was reduced from 100 μm to 65 μ m since the effective thickness of the septum would no longer be determined by the thermal deformation of their support, but rather by the thickness of the wires and their alignment.

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A first electrostatic septum unit equipped with an invar anode was installed in July 1984 in LSS6 with the almost dramatic effect of a reduction of the losses by more than a factor two. As a consequence, the septum in LSS6 has become much more reliable and the radiation doses received by staff in case of interventions was considerably lower than before. Three more invar anodes, one for LSS6 and two for LSS2 will be installed during the 84/85 shutdown.

Measurements on the existing extraction septum magnets have revealed that the insulation between the laminations which had been obtained by the blue steaming process, has considerably decreased after a few years of operation, apparently due to frequent bake-out of the magnets at about 150°. Since the copper septum is not insulated with respect to the laminations, parallel currents have developed in the yokes of the magnets, increasing their fringe field. Tests with a phosphate insulation of the laminations were carried out successfully during 1984 and a number of these laminations will be placed at regular intervals between the blue steamed laminations for the new septum magnets to be built, for electron extraction or as spares for the existing magnets.

A new external beam dump which incorporates a graphite core for better resistance against short high intensity proton bursts, was installed and commissioned in the TT60 transfer line. The temperatures induced by fast and slow extracted proton beams have been measured and indicate that intensities of up to 3×10^{13} protons per pulse can safely be dumped repetitively. Such a beam intensity at 450 GeV carries a kinetic energy of 2.16 MJ.

The vertical and horizontal superdamper systems for damping transverse coherent betatron oscillations are now complete and have been tested with beam. These tests have shown their capability of acting on the beam at frequencies in the range 3 MHz to 50 MHz. The change to injection at 14 GeV/c has modified the beam-machine characteristics so that the strong instabilities originally observed at injection and requiring the superdamper are no longer present. However, towards the end of the last fixed-target run, at the very high intensities obtained, transverse instabilities on small portions of the beam were seen at higher energies during acceleration and there was also some evidence for instabilities of this type during extraction, thus spoiling the extracted beam quality. All these effects will be studied in detail during the fixed-target run beginning in April 1985. The wideband nature of the electronics in the pick-up chain has allowed observation and clarification of the radial motion of parts of the injected beam particularly around transition and associated with beam-loading in the RF cavities.

The RF feedback system, which considerably lowers the effective impedance of the accelerating cavities, is one of the key items in the successful operation of the 14 GeV/c injection. To further improve the performance of this critical element, a new RF feedback circuit with a larger bandwidth, using the technology developed for the superdamper project, has been built and tested on the RF cavities.

An extensive maintenance programme of the RF power generators was necessary to maintain the required high degree of reliability. To this end a complete dismantling, cleaning and re-assembly of the 68 amplifiers of one of the 200 MHz power plants was carried out during the shutdowns.

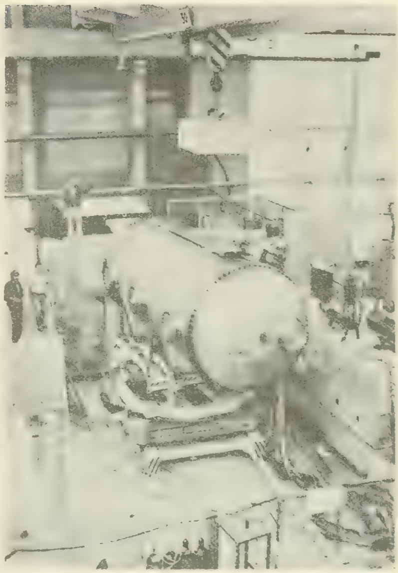
The computer replacement programme which started in 1979, has now been completed. The last 10 NORD-10 computers, which have been in use since 1973, have also been replaced by NORD-100 computers. Seven laboratory computers, which so far were used in a stand-alone mode, have been linked to a new message handling node of the SPS computer control system. This enhances considerably their usefulness for software development and ease of maintenance.

The computer systems have been upgraded to allow execution of FORTRAN-based functions. In a number of control computers the user working areas have been increased and facilities allowing the execution of multiple tasks in parallel have been added. Additional auxiliary crate controllers have been installed for the beam monitoring systems. A new hardware interface has been conceived and implemented for the linking of local microprocessors in a G64 crate to the existing multiplex system. Its design has been made compatible with the MIL 1553 standard bus in view of its alternative use in the LEP control system.

The Experimental Areas for Fixed-Target Physics

During the fixed-target programmes, all seven principal secondary beams in the North Area have been exploited to serve a total of fifteen experiments, of which five have been completed and three were taking data for the first time. Among the experiments completed was NA30, the precision determination of

Figure 4 — Test facility in the West Hall for the central detector of the LEP experiment OPAL. The tank can be laterally displaced and horizontally rotated with respect to the test beam which enters from the right. (CERN-366.08.84)



the neutral pion lifetime, in which members of the SPS Division have participated. The result, which is an order of magnitude more precise than previous measurements, has been submitted for publication.

Among the new experiments, the project to provide alternate K^0_L and K^0_S beams for a precision measurement on CP-violation in experiment NA31 reached a first stage of preparation. The K^0_L beam was successfully commissioned, following the complete installation of the decay tank, stretching over 110 m of length and providing a volume of 400 m^3, was evacuated to a pressure of 0.1 mbar. Counting rates due to decays of K^0_L from the beam in this mode of operation were recorded in the detectors of the experiment. Another major new experiment, NA34, designed to study lepton production in detail, started testing and calibrating the uranium calorimeter modules to be used.

Design studies have included a proposal to establish a link between the front end of the M2 muon beam and the Po beam serving the North Area High Intensity Facility (NAHIF). This is intended to provide the choice of recuperating the primary beam to NAHIF either from target station T4, as at present, or from T6 in conjunction with the muon beam, according to the needs of the experimental program.

Also the West Area beams were fully exploited, serving six high energy experiments and a large number of test and calibration runs mainly for detectors of the proton-antiproton and the LEP experiments. Electrons, photons, pions and protons, including protons from lambda decay, were provided to the four experiments using Omega, either for physics runs or for calibration purposes. In H3 the emulsion experiment WA75 was completed and replaced by a more sensitive beauty particle search, experiment WA78, for which the SPS Division had to plan and modify the layout.

The three test beams, X3, X5 and X7 are derived from the split H3 beam. A full programme of tests and calibrations was carried out in these beams. Considerable effort is required to study and execute the installation of new detectors, of ever-increasing sizes, in the test areas, some of which have to be installed at short notice. During the last days of the fixed-target programme the X5 beam was modified to be able to transport a calibration beam to the experiment WA1 in the neutrino counter building.

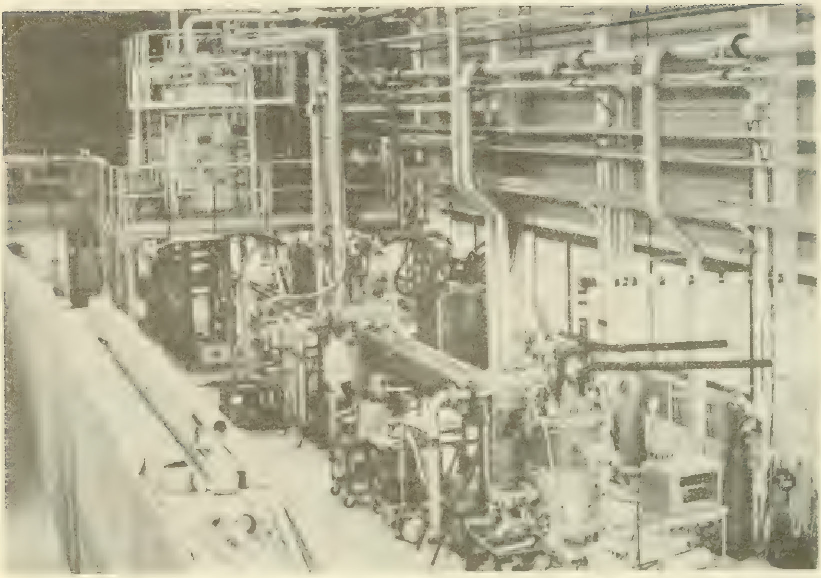
Extensions of the X7 test beam to WA79 (CHARM II) have been studied. The version chosen will have magnets installed in the former BEBC hall and will require a further 250 m of vacuum pipe. A study is underway to provide yet another test beam in the West Area, which would be derived from a second split of the H3 beam and which would be tailored to the needs of UA1. The UA1 equipment could then be removed from X5 thus alleviating somewhat the critical situation in that beam. Further test possibilities will also be provided in the North Area beams H2 and H6.

Other long term studies taking place concern the installation of 7 m diameter half rings of the LEP experiment OPAL for calibrating several thousand leadglass blocks and a calibration stage for the UA1 supergondolas.

Other Developments

The development project of a superconducting dipole magnet with a bore of 70 mm and a magnetic

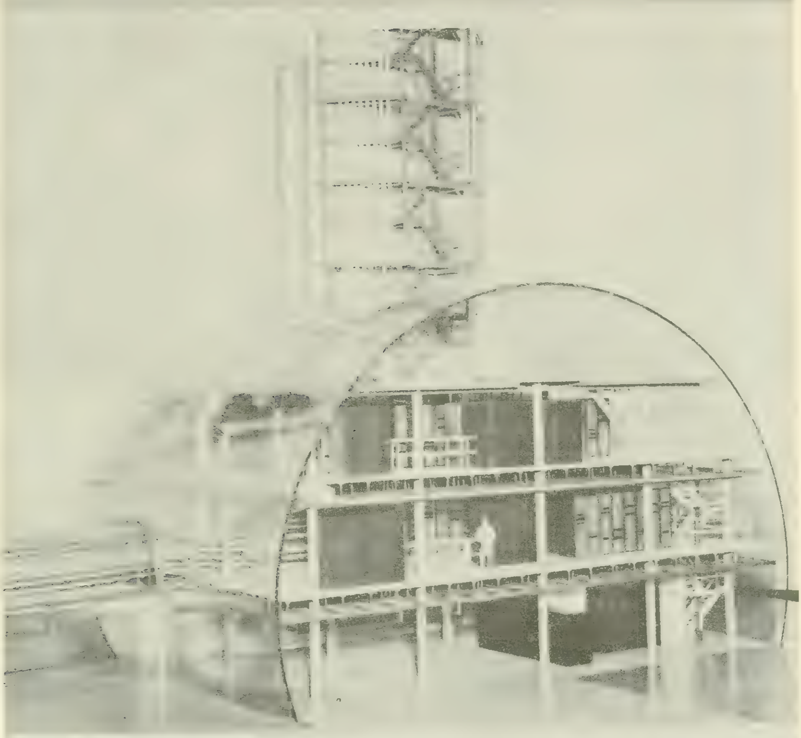
Figure 5 — Test station of the 5.5 m long superconducting dipole Po with, in the back, the dewar and the liquid helium pump and on the floor the dipole with its current leads, safety valves and Joule-Thomson expansion valves. (CERN-780.10.84)



length of 5.3 m has been successfully completed. After final assembly and testing of the magnet and its complex helium cooling system, the magnet could be cooled down in 7 days to 4.6°K at a helium flow rate of 1.9 g s^{-1}, the total static heat loss amounting to 32 W. The magnet was then excited to 4.5 kA which corresponds to a maximum field of 4.85 T in the winding and of 4.2 T in the bore. These values were achieved without any training or quenching of the magnet coil. The field integral was 22.3 T/m or 24% above the design value of 18 T/m.

Many staff members from different groups have contributed to the various aspects of the feasibility study for a Large Hadron Collider, particularly on the subjects of general accelerator physics and lattice design, the RF system, the vacuum and high field superconducting magnets.

LEP Division



Model of the LEP underground service area US65. This was constructed in order to study the layout of the cooling, ventilation and cabling installations as well as the electronic equipment racks, etc. It clearly demonstrates the size and complexity of the service areas close to the experimental areas (CERN-167.10.83)

LEP Division

Introduction

At this stage of the LEP Construction Project, eyes are turned mainly towards the civil-engineering, not only because of the many construction sites now dotted around the local countryside, but also because of its importance in completing the project to schedule. In fact, progress has been nothing less than spectacular, even in spite of two protracted industrial disputes at the principal contractors. Already the Linac and Electron–Positron Accumulator (EPA) buildings, together with the dipole magnet assembly hall, have been constructed and several more halls will be ready early in 1985. Ten of the eighteen access shafts to the main ring have reached the tunnel level and a start has been made to the tunnel itself in the 'Plaine' region. Under the Jura mountain, where rock conditions are less favourable, the junction chamber UJ 32 to the existing Reconnaissance Gallery has been excavated together with the escape shaft PZ 33 and some 800 m of the tunnel itself.

The schedule for all other machine systems is being respected with many production prototypes and series equipment already delivered, the remainder being well on the way to being manufactured or ordered, and more than two-thirds of the total project budget already paid or committed. That so much has been achieved so far is a glowing tribute to the staff, not only of LEP Division but of all the divisions who are supporting this project.

For convenience, all the construction project work is reported in this chapter and the contributions both to the project and to this Annual Report from the divisions other than LEP are gratefully acknowledged.

Sadly, the final shutdown of the ISR has to be reported; the very last beam being dumped at 6 a.m. on 25 June. True to form, however, the machine behaved in an exemplary fashion right to the end so that the last-ever ISR physics experiment could be completed successfully. The latter, experiment R704 (direct formation of charmonium states in $p\bar{p}$ annihilations), with its very reliable and efficient hydrogen gas target, used a circulating antiproton beam at various momenta between 3.5 and 6.5 GeV/c and received a total of 3000 nb^{-1} of integrated luminosity. The ISR machine was then dismantled to create work and storage space for LEP equipment and to permit some of the components to be used for the LEP and other CERN projects.

Finally, the CERN Accelerator School, to which the LEP Division plays host, deserves to be mentioned here. In only its second year of existence, an ambitious series of courses and seminars was successfully organized with demand for places often exceeding the number available.

The LEP Project

Injector System

The construction and development of the Linacs, Accumulator and transfer lines, together with the modifications of the existing PS and SPS machines required to permit their use in the LEP injection system, are the responsibility of the PS and SPS Divisions. Since however this system constitutes such a large and important part of the LEP project, it is logical to report it here.

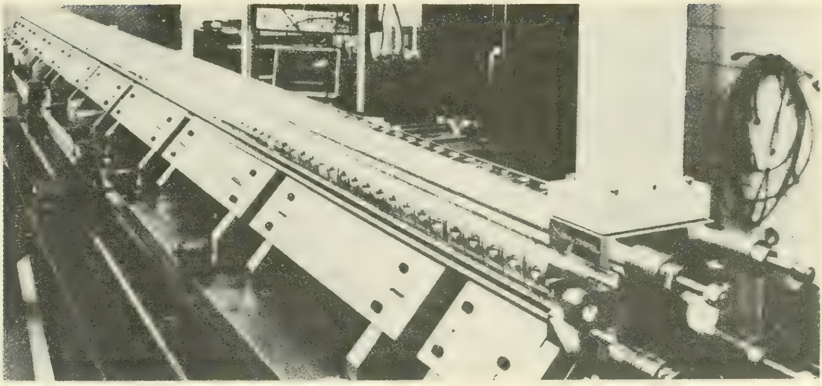
The LEP Injector Linacs (LIL)

In the continuing collaboration with the Laboratoire de l'Accélérateur Linéaire (LAL) at Orsay, all LIL systems have now been defined and specified, most contracts and orders for components and sub-systems have been placed. The overall progress is compatible with the aim of a first test beam towards the end of 1985.

The injection system for the high-current linac is still being commissioned. The gun for the low-current linac will soon be delivered while its bunching systems, as well as the low-power RF source and phasing system are under construction at LAL. The low-power RF reference line will soon be installed.

The first of a series of high-power modulators has been tested successfully and most modulator sub-systems have already been installed. The contract for the series high-power klystrons had been split between the two firms who succeeded in developing acceptable prototypes and one of them has already produced an acceptable unit. The contract for the manufacture and installation of the high-power RF distribution networks has been placed. The special RF waveguides and RF flanges are now available at the networks contractor, who has completed the installation drawings and started the production. Series production has been approved for the high-power RF windows and loads

Figure 1 — The first accelerating structure of LIL (LEP Injector Linacs) nearing completion at the manufacturers. (CERN-574.01.85)



following satisfactory tests on the prototypes. The first LIPS (LEP Injector Power Saver) system (RF peak-power enhancement by pulse compression) has been commissioned at low power with satisfactory results.

Seven of the sixteen accelerating structures (see Fig. 1) required, have been manufactured. They are delivered to CERN via LAL, where they are tested, aligned and mounted in their vacuum envelopes: one such complete accelerating section has already been installed. After initial difficulties by the different manufacturers of the accelerating structure components to meet the tight dimensional tolerances, sufficient components are now available to feed the structure production line.

All the magnetic elements have been ordered and are being manufactured, although for some elements progress has fallen behind schedule, e.g. for the FODO quadrupoles where the manufacturer failed to make acceptable coils. Orders have also been placed for all specific high-power and common control parts of the magnet power supplies and deliveries have begun. The design and layout of all the beam monitors has been finished, prototypes either already exist or are near completion and installation of all the monitors is scheduled for summer 1985. All the vacuum system components were delivered, tested and accepted during the year. A prototype electron-positron converter and associated power supply has been tested as an assembly.

LEP Pre-Injector (LPI) Controls

Both LIL and EPA will form part of the new PS controls system. Most of the hardware interface requirements have been defined and all basic CAMAC equipment ordered, while the front-end and console computers are ready for installation. Production prototypes of a powerful CAMAC-based microprocessor have been completed and its software package is under development. The software specifications for the individual systems are also in preparation. A complete and detailed proposal for the LPI timing system has been made and its realization in terms of hardware and software compatibility within the PS machine complex is under study.

The Electron-Positron Accumulator and the Transfer Lines

Progress with the design and construction is in general compatible with the target date for completion of the machine by April 1986.

Detailed magnetic measurements have been completed on the prototype EPA bending magnet, while particle tracking and optics studies have shown that its properties are correct. The first injection and ejection septa have been assembled and tests are in progress. Studies and measurements on beam-equipment interaction were pursued with particular atten-

tion to the kickers where it appeared necessary to reduce the impedances.

Tests on a mock-up RF cavity were completed and means found to damp the different parasitic resonances. All the beam measurements that will be required have been defined and, wherever possible, existing hardware has been adapted, e.g. SEM grids and moving mechanisms. A prototype beam-position monitor was also tested and its low impedance characteristics confirmed.

The PS Modifications

The prototype wiggler has been successfully tested in the DCI ring at LAL, Orsay, France. The design was then completed and the magnets will soon be ordered.

The study on the pressure rise in the vacuum chamber caused by the synchrotron radiation resulted in a recommendation to change the chamber. Even with this, degassing problems may still arise, but as there is such a large number of different components in the straight sections it has been decided to wait for actual experience with an e^- beam in the PS before taking further action. The power amplifier for the 114 MHz RF system has been ordered and the mechanical design of the cavity has started.

Civil Engineering of the LPI-Complex

The civil engineering of the building complex for LIL and EPA together with the three local equipment buildings has been completed. However, some delays were encountered with the installation of the air-conditioning and utilities.

SPS Modifications

Manufacture of the 32 single-cell standing-wave cavities ordered in 1983 for the acceleration of $e^{\pm}$ bunches in the SPS is in progress. Following the placing of the order for the 200 MHz, 65 kW power tetrodes early in the year, the first units are already being tested for acceptance. The resonant amplifier enclosure which houses each tetrode and which will be mounted on top of each cavity has been designed and the components are being ordered, while the first of the four 1.1 MW, 10 kV power supplies has been delivered.

Considerable effort is being devoted to the design of the shielding to protect the insulation of the SPS magnet coils against synchrotron radiation. Whilst inside the magnets this radiation is absorbed in the wall of the vacuum chamber because of the small angle of incidence, this is not the case at some 4000 locations where the chamber cross-section changes. Therefore, it has been decided to use a suitable combination of 3 mm thick tungsten diaphragms attached to special gaskets and mounted inside the vacuum system, and of lead pieces clamped to the outside of the vacuum chamber.

Transfer Lines and LEP Injection

The beam optics of the two transfer lines from the SPS to LEP has been finalized and all magnetic elements and their power supplies have been defined. Whereas a total of about 100 magnets are needed, only 12 new dipoles with a length of 2.8 m had to be ordered, all the other magnets being recuperated, mainly from the ISR and its transfer lines. All the power supplies for the $e^{\pm}$ transfer lines were also recuperated from the ISR. The parameters of the steel septum magnets for injection into LEP have been determined and the tender drawings are being prepared.

Three full-aperture kicker magnets and one kicker septum magnet are needed for each LEP injection channel. The former are single-turn, C-core, ferrite magnets in air, built around a ceramic vacuum chamber. The design of these kickers has started and a prototype of the ceramic vacuum chamber, with a length of 1.2 m, a width of 220 mm and a height of 70 mm, has been ordered. A model of the ferrite kicker septum magnet has been built and the measurements made on it show that a ratio of less than 10^{-3} between the magnetic field outside and inside the magnet gap has been achieved.

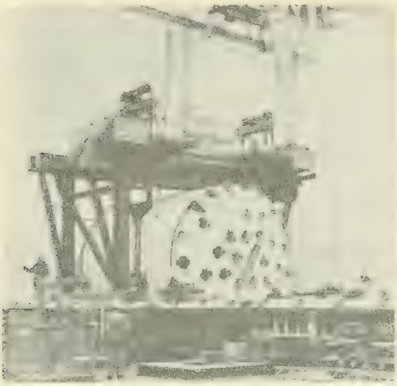
Main Ring

Construction Work

The underground work in the plain (carried out by an outside contractor) was held up by two long strikes, one at the beginning of the year and the other in the summer, resulting in a total loss of some five months' work. Despite this delay, all the construction

Figure 2 — The WIRTH tunnelling machine assembled and ready to be lowered to the bottom of shaft PM18 before starting work on the main ring tunnel. (CERN–481.01.85)

Figure 3 — On 10 October the junction was made between the LEP main tunnel and the bottom of shaft PZ33. This constituted the first geodetic connection between the surface network and some 1300 m of gyroscopically steered tunnelling; the error in the position of the tunnel was found to be less than 1 cm both horizontally and vertically. (CERN–331.10.84)



sites have been opened and the working platforms have been fitted out at points PGC1, 2, 4, 6 and 8. Ten of the fourteen shafts started at these various points have been sunk to their final depth. The water tables were crossed either with the aid of cast walls (at points 2, 4 and 6, in particular, where the walls had to be up to 40 metres deep) or by freezing the ground at points 8 and 5 and for shaft PZ 45 at point 4. Here, a large platform was excavated in the shelter of a cast peripheral wall. Two large concrete-mixing centres were set up at points 6 and 18 to serve the work sites.

By the end of summer, progress on the shafts had reached the stage at which it was finally possible to undertake the 'horizontal' excavations at points 1, 2, 8 and 18 using mobile-head cutting machines. Two timetable changes have been agreed upon in order to be able to keep to the original schedule, concerning especially the opening of the work sites at point 4 and the introduction of the first boring machine at point 18 instead of point 8, so that octant 1–2 can be dug out earlier with a full-face boring machine. Three of these machines were ordered. Two of them have been delivered to the work site and are to be set to work, one at point 18 at the end of February 1985, and the other at point 8 in March 1985. The tunnel liners are being made.

Regarding work beneath the Jura, the main LEP tunnel is being excavated from the end of the exploratory tunnel (point 32) to the Allondon fault, near point 4. Work is progressing on two sites:

- the main tunnel bored from the exploratory tunnel and its access shaft (PM 32). The connecting structure between the end of the tunnel and the main tunnel, referred to as chamber UJ 32, of a volume of 2700 m^3, has been completed, but was delayed by several months on account of difficulties associated with the nature of the rock.
- shaft PZ 33, 100 metres deep, was sunk during the first half of 1984 and the first liaison between the

Figure 4 — With several shafts already excavated, such scenes were typical by the end of the year. This one shows the bottom of shaft PX 24 seen from the vault of experimental area UX 25. (CERN–434.01.85)

main tunnel passing beneath the Jura and the bottom of this shaft was achieved on 10 October.

Although, partly owing to the problems with the ground, the work on the main tunnel was held up by some five months, it has progressed satisfactorily as far as a point beneath the village of Crozet. Almost 800 metres, i.e. about a quarter of its full length, had been completed by the end of the year. The pilot borings made every other week-end, gave an idea of the ground 120 metres ahead of the workface. Up to the end of the year, they revealed an initial region of water-bearing faults vertically below the centre of the village of Crozet. In order to avoid annoyance to the local population, CERN made arrangements with the contractor to restrict blasting to the two day shifts but, since the quality of the rock is improving, this will not unduly affect the overall schedule.

The last few months of 1984 saw the erection of the first and largest LEP building located on the ring itself and intended for the assembly of the LEP magnets and their storage before they are installed in the tunnel. The building concerned is hall SM 18, covering an area of 7600 m^2, with four bays fitted with 16 and 8 t overhead travelling cranes. The building lies close to SPS building BA7. Provisional acceptance of the main structure and the finishing work was notified on 15 and 29 November 1984 respectively. Despite the poor quality of the ground encountered during work on the foundations, the building was completed on time.

The programme for the completion of the buildings and surface structures connected with the LEP project is continuing, and includes:

- the provision of the first two buildings at point 15 at the beginning of 1985;
- a start in the near future on the second phase of ten buildings at points 1, 2 and 8;
- the start of work on the hall for assembling the vacuum chambers on the Prévessin site in February 1985;
- the forthcoming issue of the call for tenders for the third phase of twelve buildings at points 3, 4, 5, 6 and 7.

All this involves a great deal of design study and preparatory work, undertaken with the aid of two local architects and several outside design offices.

Applied Geodesy

Civil engineering activities during the year required a considerable amount of topographic support such as the preparation of plans of the shaft sites, roads, spoil tips, underground services, and a variety of other mapping requirements. This has led to a study being carried out on the possibility of creating a topographic data base for the whole of CERN and which would be compatible with the Computer Aided Design (CAD) system.

Preparatory work has continued in support of the underground civil engineering work. In the Jura section of the tunnel, the first geodetic connection has taken place between the surface network, measured by a Terrameter, and 1300 m of gyroscopically steered tunnelling. The error in closing the link was found to be less than 1 cm in both the horizontal and vertical planes.

An important operation in surface geodesy was carried out at the beginning of December using the NAVSTAR satellite system. Using the high precision time signals emitted from an on-board atomic clock, ground receivers calculated the vector parameters of pairs of survey stations. A precision of a few millimetres is expected and should be similar to that of the original Terrameter measurements.

Survey support has continued to be given to the PS, ISR, SPS and the new LEAR experiments, and the future beam line has been traced on the floor of the LIL-EPA pre-injector buildings. In addition, test beams were aligned for preparatory LEP experiments. In the PS East Area, a Cherenkov counter was installed for DELPHI, and in the SPS West Area, positioning was carried out for the OPAL central detector, the Bismuth Germanium Oxide (BGO) electromagnetic calorimeter of L3, and calorimeters for ALEPH and DELPHI.

Finally, progress was made in the instrumentation for the metrology of the SPS. An industrially-produced version of the CERN-developed Distinvar instrument was acquired in December. Two prototype automatic gyroscopes have been built and successfully tested in the LEP tunnel. This design is now open to tenders for industrial manufacture.

Theory and Parameters

Beam optics studies were completed for 60° phase advance per cell with a nominal energy of 55 GeV. A detailed parameter list was published. Lattices with 90° phase advance were also investigated in considerable detail. The closed-orbit correction was simulated to assess its performance and the necessary corrector strengths with a reduced number of monitors. Corrections of the betatron functions and the phase advances between crossing points were investigated while tolerances of the power converters were defined and positions and working modes of the wiggler magnets finalized. The LEP lattice data base on the central computers was expanded, and programs were written for the automatic transfer of information to the Survey and Installation Groups.

Work on collective effects was centred on the transverse mode-coupling instability of single bunches which is expected to be the main limitation of beam current in LEP. Better estimates of the transverse impedance were obtained and, due to their large number, the vacuum-chamber bellows were identified as the main contributors even when they are shielded. Both analytical and numerical studies were made to improve the understanding of this problem, and new designs with lower impedance have been derived. Coherent synchro-betatron resonances due to wake fields, found by computer simulation in 1983, can be explained by the action of localized impedances. A new theory of transverse mode-coupling permits calculation of Landau damping due to the spread of synchrotron frequencies in a bunch.

To enhance the polarization rate, an asymmetric design of the damping wiggler has been adopted, reducing the polarization time at 50 GeV from 210 min to less than 70 min. Improvements of the spin rotator design proposal have reduced the loss in polarization to about 5%. Plans for implementing polarized beams in LEP were presented at the High-Energy Spin Physics Symposium in Marseille.

Magnets

For the cores of the LEP dipole magnets, the steelmaker has already produced about 2800 t of steel sheet of satisfactory magnetic quality and the punching factory has delivered to the coremakers about 330000 laminations. Series production of the cores was started in summer at the two coremaking plants, one near Vienna, the other in the St. Genis Industrial Area, and by December about 200 cores had been cast. The cores are aged during three months at the factories, before being painted and delivered. Measurements of magnetic gap geometry and mechanical behaviour on the first 50 cores delivered to CERN have shown that the prescribed production tolerances have generally been met.

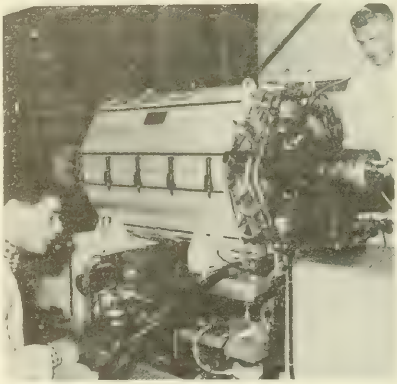
Prototypes of the standard lattice quadrupoles and of the two types of sextupoles have been received and found to have the required field quality. Minor modifications of the manufacturing process should produce a further reduction of some unwanted harmonics. Prototype correctors are expected in January 1985.

Figure 5 — Measurement of the 'magnetic' geometry of the air gap in the core of a LEP bending magnet by means of a computer-controlled carriage running inside the gap. The references are a laser beam and an electronic level gauge. (CERN–458.11.84)

Figure 6 — A production prototype sextupole, SD type, on its measuring bench. The output of the measuring coils is treated on-line by a microprocessor which computes the harmonic components of the field integral. (CERN–017.11.84)

Contracts for the supply of almost all the major components of the magnet system have now been adjudicated. Those of 1984 include the water-cooled cables and the supporting jacks for the main dipoles, the coils for the injection-region dipoles, the girders for the straight-section groups, the busbar modules for quadrupoles and sextupoles, and the superconducting quadrupoles for the low-beta insertions. The specification of the latter magnets, which have to fit into the experimental apparatus, required detailed complex design study. The contract for the water-cooled cables includes their installation into the LEP tunnel by the manufacturer.

The instrumentation for the determination of the magnetic geometry of the dipole cores is now in regular use and the benches for the magnetic measurements of the lattice lenses and those for the correcting dipoles are ready and have been satisfactorily tested. A data base has been prepared for collection and easy retrieval of information concerning the thousands of elements of the magnet system.



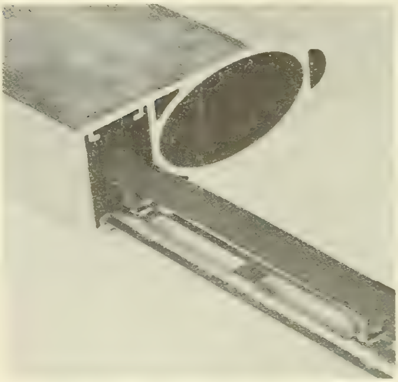
Radio-Frequency

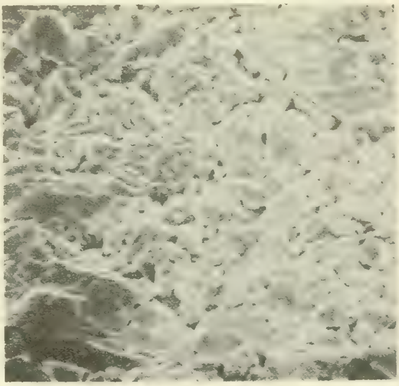
After successful testing of the production prototypes of the 1 MW continuous-wave klystrons, series production was authorized and by the end of the year two units from each of the two firms had been built and successfully tested. The tests include one-hour runs at 1.1 MW. Maximum conversion efficiencies of 68% were reached.

During the year much effort was devoted to launching series production by industry of the different components which are being assembled into the accelerating structure at CERN. By the end of the year, all these components were in production while our assembly line, including the two semi-automatic conditioning stands, had been brought into operation.

Figure 7a — A getter pump being inserted into the pumping channel of a dipole vacuum chamber prior to welding a closing plate over this channel, the water connections to the cooling channels and the end flange to the elliptical beam channel. (CERN-243.12.84)

Figure 7b — The getter strip about 900 × magnification. Its granular structure is clearly visible, this yields an active surface of 50 cm² per cm² of getter strip. (CERN-290.02.85)





Eight complete coupled cavity assemblies, each one contributing 3.1 MV peak RF voltage at 125 kW input, had also been finished. In addition, all of the rigid two-port waveguides which will be located in the LEP accelerator tunnel have been delivered and checked.

Studies have continued on the various aspects of synchronization of the two pairs of LEP RF stations and the injectors. A prototype timing unit for picosecond bunch synchronization has been built and a synchronization signal of 352 MHz successfully transmitted over a 4 km sample of a monomode optical fibre.

Theoretical and hardware development work has progressed on a reactive feedback system which maintains the coherent tune constant. This system may increase the threshold for the transverse mode-coupling instability which, as already mentioned in the Theory and Parameters section, is considered to be the most serious beam current intensity limitation for LEP.

The development of superconducting RF cavities continued and this work is reported more fully in the EF chapter. With efforts concentrated on 350 MHz units, some very encouraging results were obtained. Accelerating fields of 10 MV/m and quality factors of 3×10^9 were attained. A new cavity layout for LEP was finalized and development of couplers, tuners, and cryostats continued.

Vacuum

A large number of orders was placed in 1984 for the supply of essential components of the main ring vacuum system. Series prototypes of the extruded tubes and the forged flanges for the standard vacuum chambers made of aluminium were received; the equipment for the series production of the chambers neared completion in two firms while their lead cladding was ordered at a third one.

Manufacture of the getter strip was started successfully; so far about 3 km has been received and found to be even better than specified. The strip support system has been finalized and is being produced such that complete getter pumps are available to be installed into the first dipole chambers (see Fig. 7). Delivery of the sputter-ion pumps continued normally with 75 received by the end of the year. Special efforts went into the critical problem of corrosion resistance of many components, in particular thin-wall bellows and the feedthroughs needed for the getter strip and the ion pumps. The first of 20 mobile pump groups has been received as well as the all-metal valves for connecting them to the vacuum chambers.

In order to gain experience with a complete vacuum system, much effort went into testing a full length half-cell of the standard LEP lattice (39.5 m long), consisting of three bending magnets and a short straight section with mock-up quadrupole and sextupole magnets. Important aspects studied included

Figure 8 — Prototype of a high-voltage electrode and one of the vacuum tanks of the beam separation system. (CERN-773.10.84)

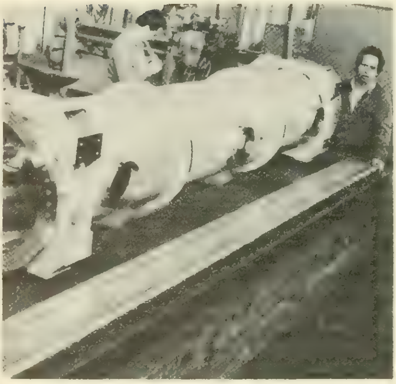
the fixation of the vacuum chamber in the magnet yokes, thermal insulation to reduce temperature gradients in the magnets during bakeouts of the chambers at 150°C, the interconnection of the chambers with flexible bellows and particularly, the aluminium gaskets used to obtain UHV joints leak-tight between room temperature and 150°C. In addition, general vacuum problems could be studied in detail such as leak testing over a large chamber length, operation of the getter and the ion pumps, many bakeout cycles and measurement of the final pressure after bakeout and several days of pumping. These tests have already given very valuable information and are being continued. Final components are being added step by step in order to have a half-cell identical to those to be installed in the tunnel.

Beam Instrumentation

For the beam orbit measuring system, 450 aluminium blocks, each machined to hold four pick-up button electrodes, are being incorporated into the aluminium vacuum chambers now in production. Four series of button prototypes, requiring aluminium-ceramic brazing, have been received from industry and are being tested, both for leak tightness and for their electrical properties, on a high precision bench recently installed in the laboratory. Studies and tests are continuing on electronic circuits to treat the button signals and to specify the signal data acquisition system.

An optical laboratory has been designed for installation at the bottom of pit 1 (US 15). This will allow polarization measurements to be made by means of a laser and analysis of the UV synchrotron light emitted by the electron and positron beams. A source for the synchrotron light has been studied in detail and will consist of two mini-wigglers located at ±60 m from the beam crossing point. Further study of a beam emittance measurement system based on synchrotron light produced in the arcs and detected in the tunnel has been made with the aid of Monte-Carlo simulation.

Measurements on a new model adjustable collimator, including three-dimensional transition pieces to reduce RF impedances, has allowed the design of all collimators to be optimized. Successful tests of a wire scanner and of a travelling-wave position monitor operating at 3 GHz, developed for the LEP injector, have been performed at LAL.



Electrostatic Separators

A full-size prototype separator with 4 m long stainless steel electrodes mounted inside a 4.5 m vacuum tank has been constructed. Particular attention was paid to the cooling system of the electrodes to ensure a sufficiently uniform cooling of their surface. This is necessary since the electrostatic separators form a discontinuity of the vacuum chamber cross-section thus creating parasitic mode losses which dissipate about 150 W in each electrode at the nominal intensity of 3 mA per beam. At present, hollow electrodes with an internal structure to produce the desired distribution of the cooling liquid are being tested. An alternative design with a single cooling channel in the middle of the electrode is also under consideration.

The detailed design and prototype construction of all other high-voltage components such as connectors, resistors, distribution units and earthing switches is in progress. The cables have been ordered and invitations to tender have been issued for the power supplies.

Power Converters

A detailed analysis of the problems related to the possibility of later extending the beam energy from 65 GeV to 100 GeV was completed for the power converters of the magnet system. This showed that, with only a minimal increase in the initial investment, the

same converters can be re-used together with some additional units when the energy is increased. In this way, the original set of converters will not be wasted and the cost of the additional ones will be minimized.

Initial specifications were written for the main components of the magnet system power converters and formed the technical part of the preliminary enquiries sent to a very large number of firms in all the Member States. Special attention was paid to the converters feeding the superconducting quadrupoles in the beam interaction regions. They will have to be very compact and highly efficient in order to fit into the restricted space at the bottom of the access shafts, and to minimize heat transfer to the cooling system.

Numerical simulations were made of the 100 kV, 40 A klystron power converter. Specifications were then established for a prototype and the main components ordered for delivery early in 1985. A 100 kV, 4 MW water-cooled dummy load was also designed and will allow the high-voltage converters to be run at full power during their commissioning.

A pre-series of 40 units of the 5.6 kV, 125 mA converters for the sputter-ion pumps was built by industry, successfully tested and installed into various vacuum test installations.

Electrical Installation

As the principles governing the electricity distribution system have been soundly established over the past few years and finalized in 1984, it was possible to go ahead with the orders for the distribution switchgear. They concern the lion's share of the equipment (400, 66 and 18 kV distribution systems, low-voltage distribution switchboards, sub-station monitoring and protection auxiliaries and 66 and 18 kV cables). The contract for the installations in the surface buildings has been concluded and commercial agreements have been signed with manufacturers of cable ladders and lighting fittings in order to standardize this type of equipment. Calls for tenders are now being drawn up so that the rest of the equipment, except for the compensators and filters, can be ordered in 1985.

Controls

For communications around the LEP site, the Time-Division Multiplex (TDM) system (tested in an accelerator environment) was further defined and a preliminary enquiry was sent out to potential European suppliers with encouraging results. Extensive transmission tests were conducted over TDM systems using the proposed token-ring network. The radio communications system in the underground areas was defined, and tenders have been invited.

The development of prototype Process Control Assemblies (PCAs) was continued throughout the year, with a first version being demonstrated in July. These use General-purpose Processing Units (GPUs) which execute functional tasks and communicate between themselves in message mode: two such assemblies are currently available for software development. PCA interfaces to the token-ring network have been developed using the 68000 microprocessor. The NODAL interpreter for the PCAs was also completed, including string-handling and full-screen editing functions.

The multidrop highway which will be used to connect equipment to the PCAs, was further developed and tested by a number of groups. Extensive effort was applied to the definition of the communication protocol between the PCAs and the microprocessors residing in the equipment control crates, while the software for the highway was developed and delivered to several users by the end of the year.

An access control system for personnel and material entering the LEP sites, or going underground via the access shafts, has been defined and prototype work started.

Cooling and Ventilation

Detailed design of the machine cooling water circuit was completed, following studies of water hammer effects and economic pipe sizing. Layout drawings were also made of the underground cooling plant installations and the surface cooling tower installations, and these were the subject of a preliminary enquiry to industry for their supply and installation.

Preparation of tender documents for the air-conditioning circuits was started and by the end of the year tenders for this equipment in shaft PM 15 had already been received. Tenders for the remainder of these circuits will be invited in 1985. Air pressurization of the personnel access shafts and aspects of smoke detection were also studied, and the layout and design of the heating and ventilation systems for surface buildings started.

Figure 9 — All aboard for a demonstration ride on the prototype of the monorail system which will be used to transport all the equipement and personnel in the LEP main ring tunnel. (CERN-202.09.84)

Hardware and software for control systems have been developed and tests completed of local and autonomous data acquisition, closed-loop regulation and programmed control circuits. The hardware and software components for the chilled water production and air handling systems have also been optimized under test bench conditions.

A fire and hazard protection policy was formulated and safe working practices assessed. This has involved the identification of potential fire and other hazards and studies of hazard detection systems, alarm and monitoring procedures using the LEP interface and computing facilities, as well as an assessment of various types of fire protection systems.

Installation and Engineering

A great effort has been devoted to the conversion of the design office staff to Computer Aided Design (CAD) techniques. Due to their cooperation and adaptability, about 50% of the mechanical design and 100% of the layout drawings are already produced in this way.

The ORACLE data base has been improved and updated throughout the year, and simulation programs were developed for use in planning the tunnel equipment installation logistics. In particular, the programs allow the installation sequences to be analysed and the necessary resources to be assessed.

Some of the equipment for transporting equipment has already been delivered by industry while the remainder is either already ordered or is now being finally defined. The monorail prototype was successfully tested and production of the components required for installing the system in the tunnel started. Orders were placed for the concrete modules and the lifts of the access shafts and for the tunnel metal framework. All the heavy cranes required will be ordered in 1985.

On the mechanical engineering side, assistance to other groups continued for design computations, specification drawings, prototype manufacture, testing, etc. The section's co-ordinating rôle continued to be important, particularly in helping to avoid interference between machine elements. New techniques were also developed for the production of ultra-thin aluminium-alloy vacuum chambers, for the use of beryllium and composite materials, and for the forming of superconducting cavities.

Radiation Control

Radiation resistance tests for many of the items to be installed in the LEP Main Ring continued throughout the year. At the same time, calculations were made for the shielding required for the double bending sections and for components in the main ring as well as on the transmission of synchrotron radiation through chicanes. Dosimetry and calibration studies for the LEP-produced synchrotron radiation were also carried out and a small project started with other institutes and industry to develop a visual indication dosimeter for use in high-radiation areas. In addition to participating in the design of the LEP access system, a radiation monitoring system for the LIL/EPA complex and the LEP klystron test area has been defined and partly installed. The development of an interface between the different LEP radiation monitor systems and the main control system is in progress.

Two environmental monitor stations for measuring natural radiation and radioactivity, as well as O_3 and NO_2 have been put into operation near shafts 1 and 5. Also, in collaboration with the Swiss Commission for surveillance of radioactivity, area dose measurements were initiated near shaft 8. Following discussions with the representative of the INB (Installations Nucléaires de Base) commission, the relevant chapters of the INB report on LEP radiation protection were completed.

Computer Services

Despite hardware problems, CAD is more and more used as a standard tool by LEP designers for mechanical drawings as well as electrical and hydraulic schematics. Many technical specifications are now issued with CAD drawings only, especially since the new dimensioning procedure of the latest version of EUCLID software is now available. Extensive use of libraries of standard objects stored in the data base (LEP components and buildings) eases considerably layout work while upgrading of the two VAX computers at the end of the year increased the available computing power for the 20 work stations. Further hardware extension is planned for 1985.

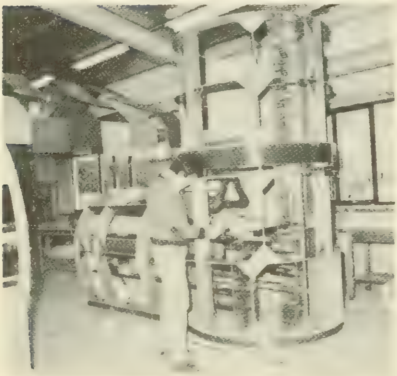
The year saw a considerable increase of data in the LEPDB data base as the applications moved from the development to the production phase. The applications which put the system under the heaviest load were the planning facility, POL (planning using ORACLE for LEP), and the installation logistics system, which is still in full development. Both the cable and the magnet test systems are in constant use, as well as the systems for handling printed-board components and the LEP inventory. All together, seven applications were in use by the end of the year with a further ten under development. Common dictionaries, which include name abbreviation, location and equipment codes, etc. are maintained for general use by all data base applications. The sharing of data between groups is becoming increasingly important. So far the project has been hampered by the unavailability of a more powerful VAX computer but a new machine is expected in summer 1985. To bridge the gap, a VAX 11-750 and an upgrade to the present VAX 11-780 have been rented and development moved to the less powerful machine. A new version of ORACLE, the relational data base management system, is expected in the near future, a test version having shown a notable improvement in performance.

Experimental Areas and Background Conditions

In parallel with the remarkable progress made on the four LEP Experiments, described elsewhere in this report, detailed designs of the experimental areas have been made, including main technical services, shielding, passageways and access routes. Particular importance has been attached to all safety aspects and models have been built to study these problems in detail in the most critical zones. A certain amount of extra work was necessary since the area allocation to experiments ALEPH and DELPHI has not yet been decided and care had to be taken to make sure that either experiment could fit in each of the two possible interaction areas 4 and 8. The gas storage and mixing

Figure 10 — LEP experiment L3. A model of the experimental area with the magnet and detector in place. (CERN-039.01.85)

Figure 11 — The hydrogen gas-jet installation after the addition of a third turbomolecular pump to increase the maximum target density by 50%. (CERN-120.03.84)



plants have been designed, including their buildings and, for the sake of standardization, all these plants will be built out of identical modules.

Estimates of synchrotron-radiation-induced backgrounds to be expected by the LEP experiments were refined and used, for example, to define the necessary aperture of the vacuum chamber. Possible distributions of beam losses in the vicinity of an experiment were studied for different operating conditions with a view to estimating the annual radiation dose to be expected at the experimental detectors. Finally, detailed studies of the synchrotron radiation created at the beam crossing points were started using the latest performance estimates.

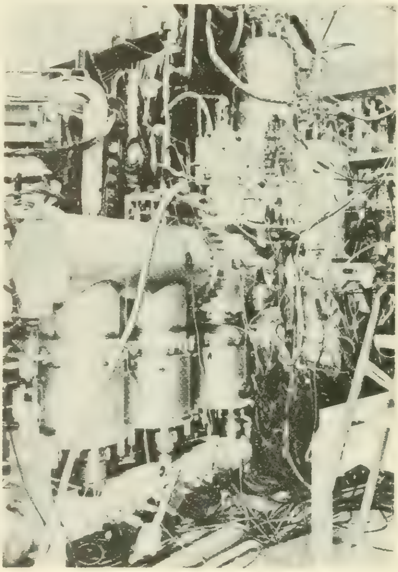
Intersecting Storage Rings

Operation for Experiment R704

In its fourteenth and final year of exploitation, the ISR was used for 12 runs, each lasting about a week, in a special mode to conclude experiment R704. This experiment required a circulating antiproton beam with a beam current of about 5 mA in collision with a hydrogen gas target in ring 2 of the ISR. The beam momentum varied between 3.5 and 6.5 GeV/c and the expected luminosity at the beginning of each run was around $2 \times 10^{30}\ \mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

Filling with antiprotons from the AA took place, in principle, every Monday, followed by a data taking period which was intended to last for 100 hours or more. This complex and ambitious programme was in reality perturbed by numerous problems leading to several difficult re-scheduling discussions. Nevertheless, a total, stable-beam, data-taking time of 973 hours was recorded and the performance figures quoted above were actually achieved during several of the runs. In all, the experiment received 3000 nb^{-1} of integrated luminosity.

With the closing of the ISR as a colliding beam facility at the end of 1983, it was possible to remove elements of ring 1 to leave more space for the hydrogen gas target of the final experiment on the direct formation of charmonium states in $p\bar{p}$ annihilation. Additional pumping could then be added to increase the maximum target density by 50% and this modification together with the installation of semiconductor detectors inside the ISR vacuum chamber were completed



and tested in time for the start of data taking in March. The target assembly and special ISR vacuum installations then performed excellently throughout the experiment with reconditioning of sublimation pumps only necessary at the Easter stop. The monitoring and control system of the target also operated well, making a vital contribution to the reliability and safety of the experiment.

Transverse stochastic cooling to combat beam blow-up caused by multiple scattering in the gas target was applied and resulted in average particle loss rates from the coasting antiproton beams of between 0.01 and 0.015% per minute. This agreed very well with the theoretical prediction and ensured good background conditions for the experiment. The average length of a run was more than 80 hours, the longest being 157 hours with a single stored antiproton beam and with the gas jet target in continuous operation.

In order to determine accurately the masses and widths of the charmonium particle resonances under study, the antiproton beam momentum was scanned in steps of a few MeV/c. This scanning was either performed in discrete steps or in a continuous fashion using the longitudinal stochastic cooling system. The use of momentum cooling reduced the fractional momentum spread ($\Delta p/p$) of the coasting antiproton beam to between 0.05 and 0.1%.

The very last ISR beam was dumped on 25 June at 06.00, thus bringing to a definitive end the glamorous career of a unique machine which will still hold the distinction for many years to come of being the only proton -proton and proton–antiproton collider in the world!

During the second part of 1984, the ISR was dismantled in order to make a number of its components, and all the buildings and floor space, available to the LEP project.

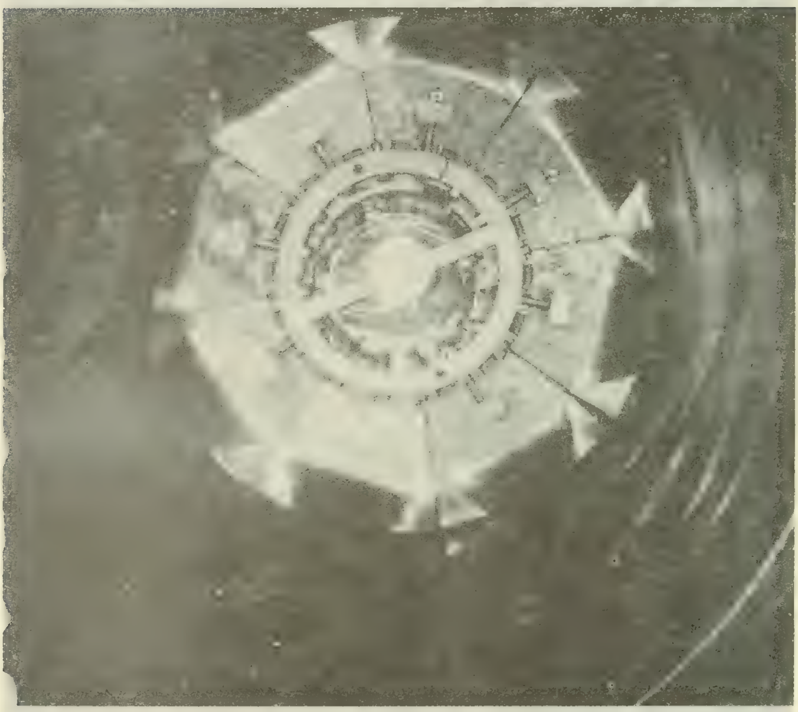
CERN Accelerator School

The activities of the CERN Accelerator School continued to build up during the year. The proceedings of the course on 'Antiprotons for Colliding Beam Facilities' have been assembled for publication in December 1984 (CERN 84-15) and form a comprehensive text book. The first 'General Accelerator Physics' course was held at Orsay and attracted over 200 applications some of which had to be refused for space reasons. In conjunction with ECFA, a workshop was organized at Frascati on the 'Generation of High Fields for Particle Acceleration to Very High Energies'. This meeting was again oversubscribed, but at the expense of some overcrowding most applicants were finally accepted. In addition, a programme of 10 seminars on specialized aspects of accelerator physics was organized. Preparations are virtually complete for a course on 'Non-linear Dynamics', which is being organized in Sardinia in February 1985 in collaboration with the American Accelerator School. At the same time preparations are well under way for an 'Advanced Accelerator Physics' course to be held in Oxford in September.

Large Hadron Collider Study

Several members of the Division participate in the design study of a Large Hadron Collider (LHC) in the LEP tunnel. With a dipole field of 10 T, a beam energy between 8 and 9 TeV seems feasible. The results of the first round of these studies were presented at the ICFA meeting in Tokyo.

Technical Services and Buildings Division



Cleaning of the water supply pipes to the SPS. Head-on view of the piston which was driven along the 10 km, 1200 mm diameter pipe between the Lake of Geneva and CERN at a speed of 5 km per hour by the pressure of the water alone. The underground progression of the piston was monitored by a magnetic transmitter and receiver. The peripheral scrapers cleaned the lining of the pipe, which has been in service since 1974. (Photograph courtesy of the Water Works Dept. of the SIG)

Technical Services and Buildings Division

Introduction

The very large number of negotiated departures (totalling 80) between 1980 and 1983, together with a few regular retirements and the transfer of personnel to other Divisions, has made it possible, while adhering to the staff ceiling set by the Directorate-General, to recruit some younger staff. This has helped improve the technical competence of certain teams, stabilize the average age of the Division and improve its ability to tackle the Division's additional workload (civil engineering for LEP, maintenance and operation of the site and mechanical engineering and related work).

After reaching 616, its greatest number, in 1974, staff numbers have now stabilized at around 480, comparable with the figure for 1964; however, the Division's workload has more than quadrupled during the same period through the considerable extension of the sites and the concomitant increase in the number of buildings and general technical installations. It has been possible to cope with this tremendous increase as a result of better organization, albeit coupled with a reduction in ·rate of maintenance operations, the acceptance of certain risks with regard to the reliability and operational security of installations and, above all, the farming out of a large number of maintenance, service and minor work contracts.

Some operations are therefore now completely in the hands of outside firms, including cleaning, on-site handling, maintenance and minor work in the buildings, and maintenance of the general electro-mechanical installations. About 450 employees of outside firms are now working permanently on the site. The figure does not include the teams responsible for new building work, which vary considerably according to the extent of the work to be done. It is probable that in a few years' time, when the building of LEP is completed, the number of contract workers will be roughly the same as that of the SB Division's own staff.

The Division's expenditure (personnel and material) amounted to 113.5 million Swiss francs, broken down under the following main headings:

	Number of people	Forecast expenditure
Construction department	64	9.2
Energy, water	–	48.2
Site maintenance, operation and cleaning	191	29.9
Central Workshops	151	14.3
Transport, equipment handling	54	9.7
Management and administration	20	2.2

These amounts do not include the following items charged to the budgets of other Divisions but which were the technical and financial responsibility of the SB Division:

		MFS
New work (ACOL, ...)		1.0
LEP construction:		
Underground work	59.3	
Surface buildings	8.1	
Work done by the SB/LE Department for other LEP Division groups	6.3	
		73.7
Alterations to existing installations		10.6
Central Workshops: jobs put out to contract.		4.1

New Works and Alterations

The three groups of the Division responsible for new works (Civil Engineering, Technical Installations, Co-ordination) have, since 1983, formed the Civil Engineering Department SB/LE. This department's prime task is to complete the LEP civil engineering programme (underground works in the plain, including connections with the SPS Tunnel, underground works under the slopes of the Jura, surface buildings at the eight LEP access points, the Pre-injector Building) under the supervision of the Director of the LEP Project and in close collaboration with the various groups of the LEP Main Ring Division. The Department's available manpower has resulted in it being made responsible for the erection of the other buildings on the Meyrin Site (Buildings Z and 0, building for the ACOL project).

Although its staff total has been sharply reduced through the many transfers to the LEP Division, the Technical Installations Group also provides technical support for certain parts of the project connected with civil engineering (electricity, ventilation, air-conditioning and pipework).

Finally, the Co-ordination Group undertakes a considerable amount of work for the planning and financial monitoring of the various operations of the Department's Civil Engineering and Technical Installations Groups.

The staff total of this department at the end of the year was 64, including 13 engineers and supervisory staff.

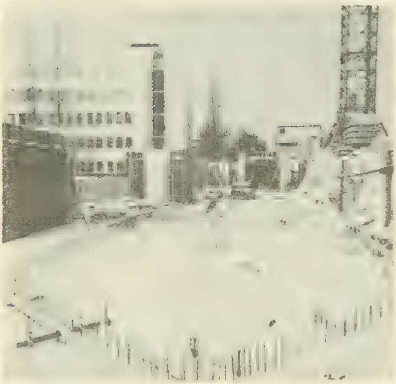


Figure 1 — The work site of the new Reception Building No. 33 as at the end of the year. (Photo J.-L. Baldy)

Figure 2 — The work site of the Physicists' Building No. 32 as at the end of the year. (Photo J.-L. Baldy)

Design Studies and Civil Engineering Work for the LEP Project

The work for the LEP programme undertaken by the SB/LE Department is described in detail under the sub-heading Civil Engineering in the section of the report dealing with the LEP Division.

Meyrin Site

A loan of slightly under ten million Swiss francs granted by the Swiss Confederation via FIPOI (Fondation des Immeubles pour les Organisations Internationales) has enabled a start to be made on erecting two buildings: Building Z or 32, near the Administration Building, to house the steadily increasing number of physicists from outside the Organization; and Building 0 or 33, for various units serving visitors from outside (physicists, contractors' staff, suppliers, pensioners, journalists, etc.). The detailed design studies for these two buildings have been completed, the calls for tender have been issued and the main contracts placed (civil engineering, electrical work, piping, heating, ventilation and elevators). The civil engineering work on Building 32 began in September and on Building 33 in November. Work is proceeding according to schedule.

The ACOL project has made considerable alterations necessary to Hall 193 (the antiproton accumulator hall), including civil engineering work in the target area, changes to the electricity supply and piping, and the construction of a 320 m^2 hall adjacent to Hall 193 (civil engineering). The design studies have been drawn up and the calls for tender prepared for the technical installation of this hall, and the work concerned is due to begin in 1985.

A start has been made on the design studies and works for a multi-purpose surface treatment building located near the existing surface treatment shop and the effluent treatment station. It is primarily intended for the cleaning of LEP's 12 m vacuum chambers and for treating superconducting accelerating cavities. It will also permit the surface treatment of large items which, with the old installations, was only possible using temporary rigs, in conditions that were unacceptable from the safety standpoint. The dimensions of the two-storey building will be 25.5 x 13.5 m, and it will house all the equipment (large vats, a cleaning tunnel for vacuum chambers, etc.) and technical installations needed for the work to be performed in the greatest safety for both personnel and the environment.

Prévessin Site

The draft plan and the detailed design studies have been drawn up and calls for tender have been issued for a 4800 m^2 hall intended for fitting the lead

shielding to and testing vacuum chambers for the LEP project. Work on building the hall will start at the beginning of 1985.

Various Alterations to Buildings and Technical Installations

The extremely heavy increase in 1983 (+ 30 %) in the number of requests from other Divisions for the fitting out of buildings and work on technical installations continued in 1984 (+ 14 %). The total number of requests, including those from within the SB Division, rose to 2850, and the value of the work done reached a total of 13.1 million Swiss francs.
This increase in the number of work requests is essentially linked to the large number of transfers of staff between Divisions and the preparations for the LEP experiments.

The most extensive work included:

- the erection of a 300 m^2 office and laboratory building for the LEP Division;
- the erection of two 600 m^2 office and laboratory buildings to house the personnel of the PS Division's ACOL project;
- alterations to Hall 175, which is to house the components of the DELPHI experiment;
- alterations to Building 173 (formerly the ICE hall), which is to become the LEP pre-accelerator control room;
- the fitting-out of Building 278, which is to house some of the LEP pre-accelerator power supplies;
- the erection of a 400 m^2 hall for storing radioactive material inside the PS Ring;
- numerous alterations to offices, laboratories and drawing offices in Buildings 30, 112, 238 and 377 for personnel of the LEP Division;
- the preparation of a storage area on the Meyrin and Prévessin Sites for bulky components of the LEP experiments (ALEPH, L3);
- numerous alterations in Hall 867;
- a minor extension to Building 72 to house the Central Workshops Quality Control Section's computer-assisted co-ordinate measuring machine;
- the demolition of the magnet supports and filling in the pits in two octants of the ISR ring, which is being converted into a testing and assembly shop for the LEP machine components.

Maintenance and Operation

Site maintenance

The sums used for maintenance of the buildings and grounds were increased to slightly more than the figures for 1983, and amounted to 1200000 SFr. for servicing and 450000 SFr. for major overhaul work.

These sums, which had had to be drastically reduced in 1978 as part of the strict economy drive, are still clearly inadequate to cover the maintenance of over 520000 m^2 of building ground-area and 350000 m^2 of roads, car parks and storage areas, which are on average more than 13 years old.

The main jobs included repairs to windows, waterproofing of roofs and the partial resurfacing of sections of roadways and car parks. A new main storm drain, 600 mm in diameter, has been laid in the central part of the Meyrin Site in order to re-balance the systems and prevent building basements from flooding during heavy storms.

Assessment of the present condition of the buildings has continued and should be completed in 1985. Its aim is to allow maintenance of the buildings to be computerized and to draw up a realistic maintenance programme for the future.

Work on improving road signs and the flow of traffic has continued, as well as the day-to-day maintenance programme for open spaces and green areas.

Cleaning

A call for tenders for the renewal of the cleaning contracts on both sites has been issued, and a new contractor will be starting work in 1985.

In this field, optimum frequency has been reached in the cleaning of offices, laboratories, workshops and halls, and any further savings would be difficult to envisage.

Technical maintenance

Technical installations were serviced according to schedule, with no major incidents.

The policy of reducing preventive maintenance in favour of keeping equipment in working order was continued.

Owing to operation in the $p\bar{p}$ mode, several items of equipment were subjected to stresses that were as

Figure 3 — General overhaul of the G2 back-up diesel generator after 50,000 hours of operation. (CERN-241.04.1972)

high as the limits of their design capacity permitted, resulting in particularly difficult operating conditions, for the SPS cooling water distribution system for instance.

A special effort has been made to control the various cooling water discharge systems to keep within the limits laid down in the Host Countries' regulations.

Special work or maintenance operations included:
- the replacement of the power equipment in the five pumps at Pumping Station 2;
- improvement and modernization of several overhead travelling cranes, especially PR116 in Building 181;
- work in conjunction with the DD Division on the installation of the new Siemens 7890;
- general overhaul of a generator set at the Meyrin sub-station, which had completed 50000 hours of operation;
- construction of the heating sub-station for LEP, Point 1;
- improvements to the Booster air-conditioning installation;
- cleaning the CERN water supply pipes from Peney and the lake.

The Division also undertook responsibility for and modification of the ISR area equipment, previously under the charge of the ISR Division, and took over responsibility for the organization and maintenance of CERN's gas detectors.

Energy-saving efforts continued, the main accent being on:
- rationalization of the lighting in Hall 180;
- alterations to the heating system in Building 2;
- introduction of a monitoring and control system for the present heating and air-conditioning installations in an initial group of buildings;

Annual variation in power, water, and fuel oil consumption from 1978 to 1984

	1978	*1979*	*1980*	*1981*	*1982*	*1983*	*1984*
MEYRIN SITE							
Active power consumption (MWh)							
– grid supply	361930	306904	323713	295291	293837	297258	205227
– stand-by generators	22194	22278	2595	2030	2085	3620	1215
Total	384124	329182	326308	297321	295922	300878	206442
Maximum instantaneous power (kW)	77400	71000	69500	60000	61000	64000	38000
Cooling water (1000 m^3)	7114	6808	5964	5494	6123	7047	7328
Drinking water (m^3)	208315	59276	45967	40883	45201	26539	45001
Heavy and light fuel oil (metric tons)	13162	13334	8195	7493	6576	7092	7112
Gaz (m^3)	26723	31755	25831	24486	24548	25343	22748
	1978	*1979*	*1980*	*1981*	*1982*	*1983*	*1984*
PRÉVESSIN SITE							
Electricity (controlled by SPS Division):							
– Active power consumption (MWh)	303556	327038	221966	252146	357988	369037	424106
– Peak power (kW)	246000	212000	192280	177603	182877	236403	206530
– Average power (over 10 min) (kW)	73000	71400	80800	83000	82000	88200	76570
Cooling water (1000 m^3)	11989	13043	8554	10662	13760	13788	15115
Heavy fuel oil (metric tons)	1281	1302	1245	1348	1278	1348	1014

Figure 4—Machining of TPC components for DELPHI using a numerically controlled milling machine. (CERN-187.05.1984)

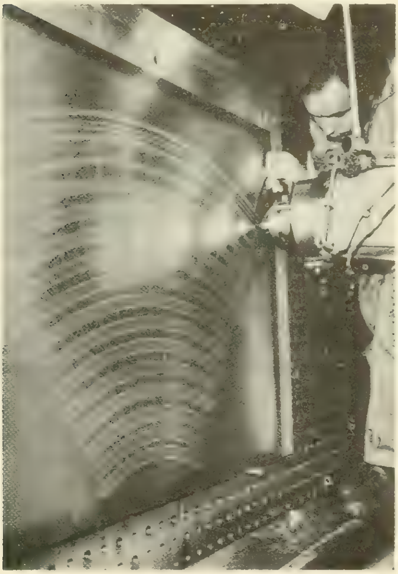
– heat recovery from the condensers of the cooling units in Building 510.

A start was made this year on the projected earthing of the 18 kV power system on the Meyrin site, while the system for computerizing the maintenance of the equipment under the Group's responsibility became operational.

Central Workshops

The Central Workshops Group made an active and often unique contribution to a large number of projects, both for the Machine Divisions and the various experimental groups.

Several major items of equipment were added during the year to the Group's machine park (an installation for immersed ultrasonic testing of components 4 m long and a computer-assisted co-ordinate measuring machine). In addition, the work site for the new Multi-purpose Surface Treatment Shop was opened. This shop will be fitted with a 25 m machine for the chemical cleaning of the LEP vacuum chambers, which was designed and built by the Group.



Mechanical Engineering Section

This section made vacuum tanks and electrodes for the LEP and SPS Divisions, tanks for cryostats for the LEP superconducting cavities (EF Division), an evaporator tank (EP Division), prototypes for various TPC/DELPHI experimental groups (EF Division), a stack-core cooling pick-up, and fast kicker magnets (PS Division). One interesting activity was the manufacture of the components for a lithium lens.

The mechanical engineering fitters assisted in work on the DELPHI, WA79 and NA31 experiments, in particular.

A special milling machine had to be built to dress the aluminium welds of the 14-metre-diameter coil for experiment L3.

Sheet-Metalwork/Welding Section

The main jobs done by this section included:

LEP Project: A prototype electrode 4 m long, consisting of two longitudinally welded half-sections of 2.5 mm gauge stainless steel, without any deformation or warping, was made for the electrostatic separator. A complex system of ribs between these two half-sections keeps the assembly rigid and permits the welding of the many baffles which channel the internal cooling fluid.

AA Project (improvement): An external vacuum tank, 700 mm long and of circular cross-section, of 2 mm gauge stainless steel, manufactured to very close tolerances, was built for stack-core cooling at 4.8 GHz. Inside, this tank is fitted with an octagonal shielding system ending in truncated pyramids with an octagonal base. The specified tolerances ensure that the shielding can be slid inside the tank without play; the work demanded technical skills of a very high standard.

LEAR Project (improvement): This project required the construction of magnetic shielding consisting of interwoven stainless steel wires (0.5 and 1 mm in diameter) forming a truncated conical structure with a curved rather than a straight generatrix.

Thin Sheet-Metalwork Section

This section's resources were widely used for the manufacture of superconducting cavities, either of niobium or of copper, these last to be subsequently coated with niobium by sputtering.

Niobium cavities: Electron-beam welding was used to make two single-cell 352 MHz cavities and one four-cell 352 MHz cavity.

Copper cavities: One four-cell 352 MHz cavity was built, 3 mm thick and 755 mm in diameter, making an assembly 2.4 m long. TIG welding was used in its assembly. Two electron-beam welded, single-cell 500 MHz cavities, made of high conductivity copper, were also built.

In addition to the copper cavities, the Section built a four-cell 352 MHz, steel cavity by spinning and TIG welding. This cavity is intended for examining the niobium film on copper samples that may be placed at various points inside it in order to determine the ideal shape for the niobium cathode used in sputtering. Niobium cathodes and screens were built for the same purpose.

Work was also done on the manufacture of deflectors of 1 mm gauge titanium sheet for GSI (Darmstadt) septa and for the LEAR Project (25 identical components), titanium screens for the SPS Division and copper collars for ceramics brazing in the SPS/LEP accelerating cavities.

An evaporation tank was also manufactured for use in thin-film work in the Group.

Special Techniques Section

This section has several workshops and laboratories.

The Mechanical Engineering Support Workshop performed a great deal of machining, often requiring a high degree of precision and the use of several techniques. The main jobs included the construction and assembly of several beam monitors (SEM-grids) for LEP, LEAR and the Linac, the building of thin-walled (0.4 ± 0.02 mm), light-alloy cylindrical chambers, the manufacture of 570-pin permeameter connectors (LEP), special windings for magnetic field measurements (PS), and a vacuum chamber and miscellaneous tooling (LEP) for the Group's Thin-Film Workshop.

The Vacuum-coating Laboratory provided a large number of coatings, generally metallic (aluminium, titanium, chromium, etc.) on a variety of substrates (mylar, glass, alumina, quartz, optical fibres, etc.). It is worth noting the high reflective quality (80% at 160 nm) obtained by evaporation during the manufacture of prototype mirrors for the DELPHI experiment. To improve the quality of the mirrors, the Laboratory has been examining plans for a reflectometer for monitoring reflectivity in the ultra-violet and visible spectrum. A new six-cathode sputtering machine has been made for the surface doping of ceramics used in the r.f. cavities (LEP). A start has been made on the manufacture of mirrors by replication; preliminary tests have shown that prospects for series production of mirrors (DELPHI) are promising.

The Plastic Scintillator Workshop has made hodoscopes (UA6), various types of prototype scintillation counters (UA2, OPAL, DELPHI, SPS), and calorimeter components (UA1, DELPHI, WA70). Plastic optical fibres are becoming more and more widespread, and the Workshop has developed small tools suitable for this new kind of work. Methods of optical measurement have been developed for examining problems involved in connecting fibres. Several workshops contributed towards the construction of the first scintillating-fibre calorimeter.

The Polymer Workshop's activities were considerable and highly varied. The main jobs concerned the manufacture of elastomer-silicone seals for vacuum tanks (LEP, L3), the assembly of lead-glass blocks (OPAL), the manufacture of mouldings (connectors, collectors, spark gaps, optical seals) (LEP, PS, SPS), the manufacture of polyurethane components (EP, SPS, LEP), the production of coatings (PS), and various types of vacuum impregnation (SPS, PS).

The associated techniques of scanning electron microscopy and X-ray spectroscopy were used in the examination of niobium surfaces on a number of samples as part of design studies for the r.f. superconducting cavities (EF), in the investigation of fissuring phenomena in lithium targets (SPS), in the detection of traces of asbestos in electric cable sheaths (TIS), in the examination of the diffusion of lead in lead/tin coatings (LEP), and in the analysis of numerous cases of corrosion and the contamination of detector components by inorganic compounds.

Surface Treatment Section

As in previous years, the range of chemical or electrolytic treatments was very wide. It included:

- the chemical polishing of niobium r.f. cavities (350 and 500 MHz cavities, in the form of both elementary half-cells and assembled single and four-cell cavities);
- the treatment of copper r.f. cavities to be coated with niobium;
- various selective electrolytic deposits on components of the lithium lens (antiproton source);
- the silver-plating of ceramic feed-throughs in the 200 MHz SWC ('Standing-Waves Cavity') (SPS);
- the application of 100 μm copper coatings to two r.f. cavities (LIL);
- treatments made to three accelerating and storage cavities (LEP Division);
- the mechanical polishing of ZS vacuum tanks and of titanium and aluminium-alloy electrodes (SPS Division);
- the mechanical polishing of a prototype ZD vacuum tank and of stainless steel electrodes (LEP Division).

Printed-Circuit Board Section

The steady demand from users of conventional printed circuits has continued. During the year, there was a marked increase in requests for multilayer circuits, and the section made more than three different types every week. Their complexity and definition (the width of the conductor tracks) are also increasing. It is not unusual to have to make six or eight-layer circuits with holes 0.4 mm in diameter, and circuits with flexible links (flexo-rigid circuits). The average delivery time for such circuits has been eight working days.

It is becoming general practice to apply solder masks to these circuits.

The new installations commissioned during the year (silk-screen printing in a clean room under a laminar-flux hood) have facilitated the successful production of prototype hybrid circuits for micro-strip detectors (EF Division).

Chemical Laboratory Section

This laboratory performed a large number of tests during the year as part of a study of corrosion phenomena in cooling circuits of septum magnets (PS Division), quadrupole magnets (LEP Division), aluminium coils (experiment L3), and heat exchangers (PS Division and pilot greenhouse).

An investigation was made into the reasons for surface irregularity in niobium superconducting cavities after chemical polishing, a spray diffuser for electrolytic polishing solutions was made (localized polishing), and localized treatments were performed on 500 MHz cavities using a solution specially developed to prevent chemical attack.

Work in the field of chemical micro-machining included the photo-engraving on aluminium-coated silicon substrates of patterns 5 μm wide and the production of lead grids consisting of 24 μm wires for detectors. Other planned types of detector required the tinning of ball bearings 1 mm in diameter (EP Division).

Heat Treatment Section

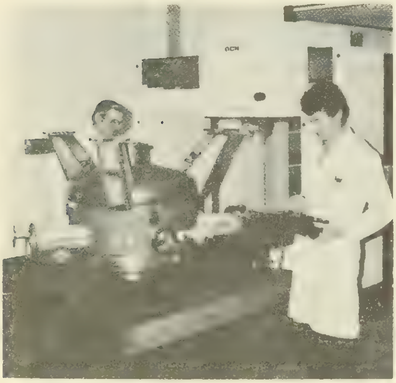
This section produced some fine work for the various current projects and experiments, including:
- coaxial feed-throughs for the power supply to the HR-SMH septum magnets operating in an ultrahigh vacuum, the corresponding septa, and the brazing of couplers, stainless steel sleeves for the connections of the cavity cooling cylinders and waveguides (LIL-EPA);
- the manufacture of ceramic feed-throughs on power inputs of 200 MHz storage cavities (SPS);
- technical assistance to various firms in making brazed connections to storage and accelerating cavities, the brazing of piston tuners and copper/aluminium oxide/copper brazings for 100 kW coaxial feed-throughs (LEP);
- a large number of brazed connections on stainless steel/niobium components and niobium/aluminium oxide/niobium coaxial connections for superconducting cavities, some of them for the Kernforschungsanlage project, Jülich, and the assembly of prototype coaxial feed-throughs for the TEXTOR project (EF).

The section was also involved in various other types of work with ACOL, LIL, etc.

Quality Control Section

About an equal number of working hours was allocated to metallurgical studies and metrology. The former included work aimed at preventing premature failures of the LEP damping loop bellows, work on the antiproton source, inspection of the electron beam

Figure 5 — Inspection of a vacuum chamber at the Quality Control Section using the computer-assisted measuring device. Inspection time was reduced by 60% with respect to manual operation and included the writing of a programme for this single component. (Photo C. Boudineau)



welds of the aluminium coil in experiment L3, examination of the stainless steel for the ACOL project, and various inspections of components for the LEP project.

One of the section's noteworthy acquisitions is a semi-automatic device for detecting internal faults, using immersed ultrasonic testing on components of any shape up to a volume of 4000 x 800 x 600 mm.

In metrology, work was done in particular on items for the LEP project (pick-up blocks, vacuum chambers and magnet laminations), and also on the vacuum chamber of experiment NA31 and various components for the ACOL project.

A high capacity (1050 x 900 x 600 mm) computer-assisted co-ordinate measuring machine was commissioned this year, greatly reducing operating times (by 20 to 80% depending on the components concerned). The time taken to inspect magnet laminations, for instance, has been cut from five days to one (after writing the programme).

Services and Projects

The many design studies undertaken by the Group's Design Office included the development of a vertically and horizontally adjustable attachment system for the HPC (High-density Projecting Chamber) modules and the tooling needed to fit them in circular array inside the vacuum tank for the DELPHI experiment; the building of a weld-bead milling machine for the coil of experiment L3, the manufacture of a guillotine for detaching the weld-pool support bars, and an elevating table for the lower vacuum chamber of the electron-beam welding machine.

For the PS Division, two r.f. cavities were designed and built for the ACOL and EPA projects.

All the sections of the Group have made use of the services of this dynamic team. Thus, the Sheet-Metalwork/Welding Section obtained a precision XY table with built-in turntable (modification to the small electron beam-welding chamber).

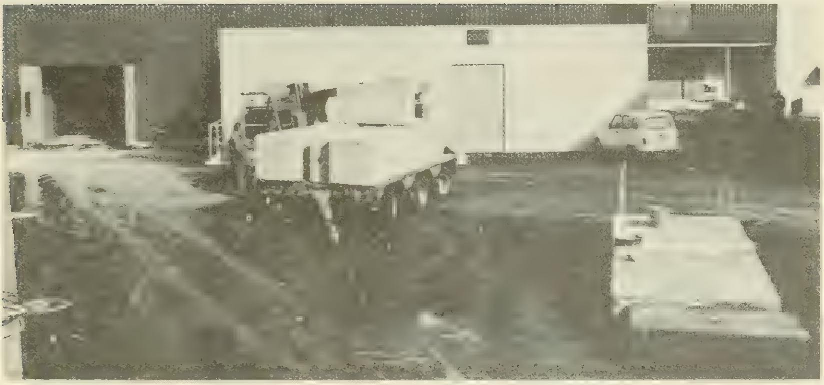
The Multi-purpose Surface Treatment Shop, now being built, will be fitted with a machine 25 m long for cleaning the LEP vacuum chambers, entirely designed by this office. Likewise, the 6 m long furnace salvaged from the ISR Cleaning Shop, with its door-opening system considerably modified, will be installed in this new workshop. Finally, a new installation for silk-screen printing in a clean room has been developed for the Printed Circuit Board Section.

Sub-Contracting Section

Work in many technical fields was required of this section, including:

- Surface treatments: Special coatings for LEP cavities and chambers, for which a large number of contracts have had to be prepared;
- Mechanical engineering: for Experiment NA31, for which very large convex bases (3 m in diameter) and a helium tank 27 m long and 3 m in diameter have been built, while 180 printed circuits 2500 mm long and 1250 mm wide have been machined and drilled;
- ACOL: Manufacture of large cavity components;
- Experiment L3: Machining of large coil components;
- AA project: A great deal of work with short deadlines for the high-precision mechanical assemblies, including the manufacture of seven vacuum tanks;
- DELPHI: Manufacture of special connectors;
- Multi-purpose Surface Treatment Shop: Construction of a machine for cleaning the LEP vacuum chamber;
- Printed circuits: Placing of new contracts, including one in Greece (the first contract for this country); Numerous very large multi-layer printed circuits have been produced for all the current projects.

Figure 6 — Handling of the shielding blocks for LIL outside the recently completed Building EB2. (Photo J.-L. Baldy)



Transport and Equipment Handling

At the end of the year the vehicle fleet numbered 804, including 426 passenger cars, 101 utility vehicles, 23 lorries, 13 tractors, 28 trailers, 81 fork-lift trucks, 2 cranes, 13 cross-country vehicles, 12 items of civil engineering plant, 54 horticultural machines and 51 machines of various kinds for the Cleaning Section and the Fire Brigade.

The distance covered inside the Organization's grounds and in Europe by all the registered vehicles has reached the impressive figure of 3 178 000 km.

The vehicle fleet also includes 319 mopeds and 346 machines specifically designed for handling equipment in the accelerator tunnels (tractors, trailers, bogies, etc.).

Discussions are being held with the LEP Division installation groups and the experimental groups with the aim of making the fullest possible use of the existing fleet, supplementing it by specific purchases of machines for the transport, handling and installation of the various components of the LEP machine and its experiments.

Whilst the entire fleet of vehicles and plant is maintained by the garage workshops of the Transport and Equipment Handling Group, some of the routine work is carried out under a servicing contract.

The Group provides transport for official meetings at CERN, conferences, visits and journeys off the sites; moves equipment over long and short distances on the sites or elsewhere; operates general services (refuse collection, the large number of removals resulting from staff transfers to the LEP Division, etc.); and moves all the equipment needed in all the assembly and experimental halls and in the machine tunnels.

Special activities included:

- the transport of equipment and assistance in the assembly work for the exhibitions in Vienna, Munich, London and Helsinki;
- the organization of transport for the 1984 Open Day and the 30th Anniversary of the Organization;
- the transport of the LEP pre-injector structures and accelerating sections from CERN to Munich and Paris and back to CERN;
- equipment handling during the machine shutdowns in January and February, and also throughout the year, as scheduled;
- the dismantling of the ISR ring, and the beginning of dismantling work on the BEBC and the neutrino experiment;
- the start of installation work on the LEP pre-injector.

ADMINISTRATION

The "financial data-base" group of the Management Information Department at work. (CERN-381 01 1985)

Documentation Department

Introduction

The demand for the various services of the Documentation Department was sustained at the record levels of the previous year. It looks as if the consequences of the vitality of the physics programme, of the progress of LEP construction and of the increased number of CERN Users, have established a new regime for the Laboratory infra-structure. In some areas of work, reorganization and the adoption of more modern technology have made it possible to absorb most of the 50% increase of the past two years. In others, however, the increased demand cannot be satisfied due to limited resources.

In addition to the bulk of routine work, the Department had many interesting tasks to accomplish during the year. For example the events to mark the 30th Anniversary required special efforts from almost all Sections. The Department was responsible for an exhibition of historical documents, for the anniversary brochure and concert programme, and for the audio-visual equipment at the anniversary ceremony itself. It involved fascinating literature searches in the library and archives, imaginative work from the exhibition team, and brochure design and production of high quality.

There was good progress in the development of the office automation system, NOTIS, where the Department has worked in close collaboration with Norsk Data to mutual benefit. The number of users on the system doubled in the course of the year and communications, both between these users and to others on the site, continued to improve. The system is having an impact on administrative efficiency and working methods.

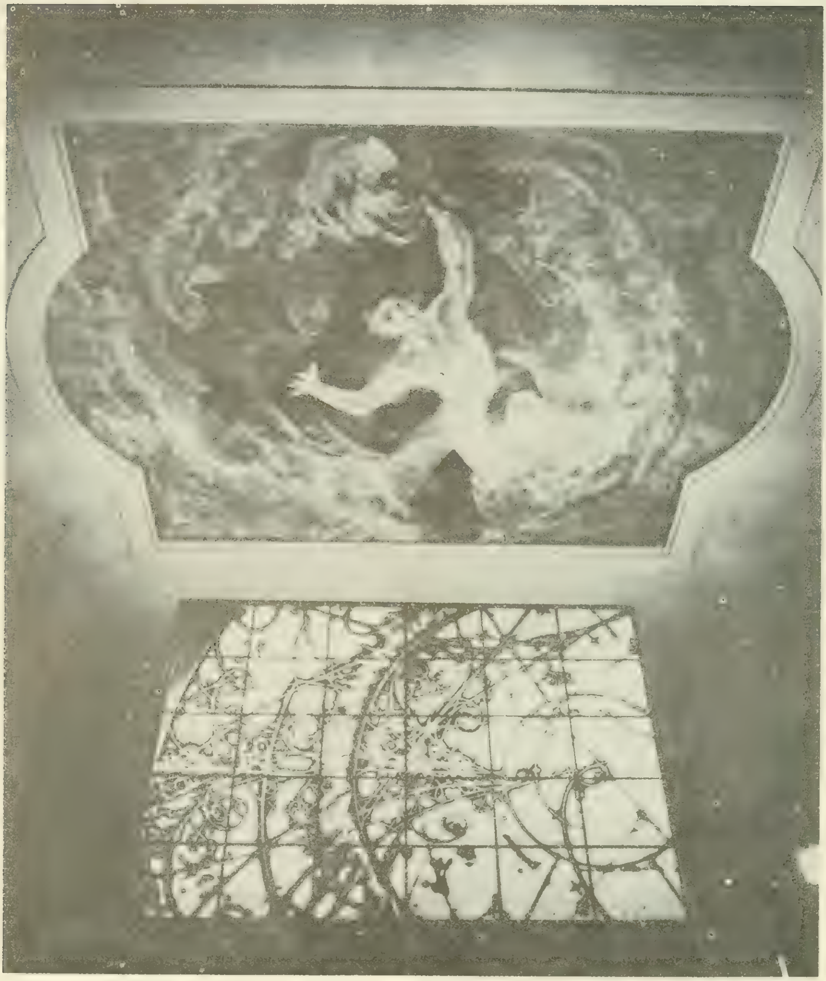
Figure 1 — During 1984 the 25th anniversary of the annual series of CERN concerts was celebrated. A special programme of concerts was arranged for this event with generous support from the Member States. The concert brochure, which had this photograph on its cover, was designed and produced in the Documentation Department.

The Work of the Sections

The strain of the increase in demand for services was particularly felt in the printshop where users understandably apply a lot of pressure to have their work produced quickly. It was necessary to introduce a second high-speed photocopier during the year; this machine has automatic stapling which relieves, a little, the assembly side of the printshop operations that has become the bottleneck. A study has been made of equipment which could substantially increase the capacity of the assembly line. In view of the higher volume of work and of the anticipated increases in paper costs (up 25% in 1985), alternative ways of financing and operating the printshop are being studied.

There are now some sixty terminals on the Norsk Data office automation system, NOTIS, with linked computers serving the DG Services, PS, TIS, PE and DOC. Communication between all these sectors is now very easy and the Index and CERNET links to others systems on the site have been strengthened. There has been more emphasis on introducing new abilities in addition to those of word processing and communication, such as access to small data-bases, a spread-sheet and business graphics. There has also been effort to implement links to office automation systems of other manufacturers. CERN has continued to collaborate with other NOTIS users on the definition of, and response to, office automation needs via the user group NOCUS. A faster and more versatile phototype-setter was commissioned during the year and a new version of the NORTEXT phototype-setting

Figure 2 — The major CERN exhibition during the year was at the prestigious Deutsches Museum in Munich. This illustration shows one of the exhibits, an enlargement of a photograph taken in the BEBC bubble chamber, set off against a painting on the roof of the Ehrensaal where the exhibition was located.



software with additional features, such as the ability to produce soft-copy on a cheap graphics terminal, is being evaluated.

In the Library the cataloguing module of the automation system, using the ISIS software, became fully operational. Over 8000 entries were added to the preprint data-base and the book data-base grew to 6600 entries with retrospective cataloguing back to 1980 and cataloguing of most of the books which are borrowed. The periodicals data-base contains titles and budget information on all the periodicals in the Library. CERN publications have been in very high demand, particularly those relating to the W and Z discoveries, and the number of reprints distributed by the Publications Exchange Section has increased considerably.

The Study Team for CERN History issued a dozen reports during the year covering the period up to the ratification of the Convention in September 1954. A very successful seminar on this period, organized by the CERN History Advisory Committee and the Study Team, was held on the occasion of the 30th Anniversary celebrations with the participation of a number of the pioneers of CERN. The CERN archivists assembled historical documents for an exhibition which included the original CERN Convention and some Instruments of Ratification, kindly loaned by UNESCO.

The volume of work in the Translation and Minutes Section remained at a high level, driven by the large number of meetings which had to be serviced. This involved the translation of discussion documents and minutes into French and, to a lesser extent, into English and German. Many contract specifications, mainly concerned with the LEP project, and other technical and administrative documents required translation and there were also requests for translations from other languages such as Italian and Portuguese.

A readership survey organized for the CERN Courier brought a high (over 3000 replies) and very positive response with some 95% of the readers who replied to the questionnaire declaring their satisfaction with the journal. The 'Images' editions of the Weekly Bulletin appeared a record number of times during the year and a new edition of the visitors' brochure 'Presenting CERN' was produced in French, English, German and Italian. Amongst the documents edited by the Scientific Reports Section were the 1983 Annual Report, the LEP Design Report, a series of yellow reports, many preprints, the ALEPH technical report to the LEP Committee and the last edition of the CERN Users' Guide. The work of this Section is greatly appreciated by the CERN scientific community.

The CERN Exhibition visited Germany during 1984 being installed for five weeks at the prestigious Deutsches Museum in Munich. The exhibition was inaugurated by Dr. Albert Probst, Parlamentarischer Staatssekretär für Forschung und Technologie. It attracted many thousands of visitors and a successful series of lectures and a round-table with representatives of German Industry were organized in parallel. Apart from the exhibition in Munich, it had been hoped to concentrate efforts on improving presentations on the CERN site itself. Unfortunately this proved impossible because of demands for participation in other exhibitions in Tokyo, Bergen, Malmoe, Berlin, London, Leipzig, Bellegarde, Oxford, Genoa and Vienna. In addition the Visual Techniques Section helped in many aspects of the 30th Anniversary celebrations.

The messenger service in the Mail Office was transferred to service contract without perturbation. The techniques used in the Mail Office, particularly in the expedition of mail, were examined to search for aspects of the work which could be automated so as to help cope with the greatly increased throughput. The introduction of a report collator has made a significant saving in manhours and the first steps have been taken to achieve addressing of envelopes in the Mail Office using address lists held on computer at any location on the CERN site.

Finance Department

Introduction

In 1984, the workload of the Finance Department reached an unprecedented level owing to the number and complexity of the matters with which it had to deal. This increased volume of activity, which affected every service in the Department, was largely due to the construction of LEP. However, the Department had to come to terms with new situations arising from increasing research requirements, in particular the LEP experiments, and had to assume these new responsibilities with no change in staff numbers and with a reduced budget. It is clear that any further reduction will inevitably jeopardize the quality of the services provided, especially if, as seems likely, the high level of activity during the year is subsequently maintained or surpassed.

Purchasing Service

Although a few improvements have still to be made in certain areas, the introduction of the COPICS data-processing equipment into the Purchasing Service is now virtually complete. Wider application of the system ensured an increasingly efficient use of the data collected in the commercial, technical and financial fields and made it possible to deal with matters more rapidly. To optimize use of the printers and to speed up the publication of documents, the order forms have been redrafted in both English and French to avoid stoppages due to the change of language.

In 1984, in view of the construction of LEP and the development of experiments which have to be organized around the LEP machine, the activities of the Purchasing Service reached an unprecedented level both in terms of enquiries to potential suppliers in the Member States and of the number of administrative operations. Without any reduction of its day-to-day activities, the Service issued 95 calls for tender for an amount of more than 200 000 Swiss francs, or an average of one call for tenders every three working days, compared to 59 in 1983. Price enquiries were also issued for the 1912 large calls for tenders, compared to 1709 in 1983. The number of contracts concluded increased from 65 in 1983 to 100 in 1984, while 27 324 orders were placed and 63 254 invoices were handled.

During the past year, 75 one-day technical and commercial exhibitions were arranged by suppliers from the Member States. In October, an exhibition of British industry was held in which 36 firms took part. In parallel with this exhibition, the exhibitors organized 11 technical lectures to present their products.

In the light of the rapid technical developments in the field of optical fibres, a one-day conference was organized to consider their use, attended by CERN users and representatives from 12 firms. This highly successful conference, consisting of presentations and discussions, was followed by an exhibition of the products of specialized firms.

Financial and Accounting Services

The exchange rates between various currencies and the Swiss franc were rather erratic during 1984 due to the considerable increase in the value of the US dollar. Table 1 shows variations at certain dates.

Table 1 — Rates of exchange

	Rate as at 3.1.1984	1.3.1984 %	2.5.1984 %	1.7.1984 %	1.9.1984 %	1.11.1984 %	28.12.1984 %	Highest	Lowest
FRF	26.10	+ 3.44	+ 2.68	+ 4.41	+ 4.02	+ 2.87	+ 3.07	27.88	25.85
DEM	79.85	+ 4.26	+ 3.07	+ 4.82	+ 4.32	+ 3.19	+ 3.14	85.43	79.10
ITL	0.1315	+ 1.33	+ 1.33	+ 3.23	+ 2.09	+ 0.95	+ 1.71	0.1391	0.1302
GBP	3.15	+ 2.38	− 0.48	− 0.16	+ 0.16	− 3.65	− 4.45	3.2455	2.9847
ATS	11.30	+ 4.51	+ 3.72	+ 5.58	+ 4.87	+ 3.63	+ 3.72	12.254	11.195
BEF	3.91	+ 3.83	+ 3.32	+ 5.37	+ 5.63	+ 4.09	+ 4.86	4.2415	3.8639
DKK	22.05	+ 2.95	+ 1.81	+ 3.40	+ 3.85	+ 3.40	+ 4.31	23.47	21.78
NOK	28.05	+ 3.03	+ 3.39	+ 4.10	+ 3.39	+ 1.07	+ 1.60	29.71	28.04
SEK	27.21	+ 2.53	+ 2.90	+ 4.92	+ 6.58	+ 6.02	+ 6.02	29.47	27.1050
NLG	1.05	+ 3.87	+ 2.81	+ 4.64	+ 3.80	+ 2.81	+ 2.53	75.67	70.30
GRD	2.20	− 2.73	− 4.55	− 4.55	− 5.45	− 9.09	− 9.09	-	-
USD	2.185	− 0.57	+ 2.75	+ 6.51	+ 10.07	+ 13.96	+ 18.65	2.6030	2.1025

Note: The variations are all calculated according to the rate of exchange as at 3.1.1984.

The 1984 budget sustained a loss of purchasing power of some 2.5 million Swiss francs following the decision of the Council, in December 1983, to grant a 2.51% cost variation index instead of 2.88%. Within this total figure, the indexation of personnel expenditure was reduced from 3.79% to 3.16%.

The cash position of the Organization was satisfactory during the year as most Member States paid their contributions earlier than in 1983.

The rates of interest available on the Swiss money market went up during the second half of the year due to increased rates in the USA, as shown in the Fig. 1. The favourable cash position and the higher interest rates available on the Swiss franc and other currencies enabled the Organization to increase considerably the amount received as shown under 'Income' in this report.

As shown in Table 2, on 31 December, the contributions outstanding amounted to 25 MCHF including a balance for 1983 from two Member States.

Table 2 — Contributions outstanding on 31.12.1984

Member States	*Swiss francs*
Greece	2'830'659.96
Italy	1'039'194.58*)
Spain	21'097'143.40
Total	24'966'997.94

*) Paid in early January 1985

In December 1983, the Council approved a budget of 701.07 million Swiss francs for 1984.

The accounts can be summarized as follows:

Income

	Budgets (millions of Swiss francs)	*Accounts* (millions of Swiss francs)
Contributions from Member States	693.84	693.84
Brought forward from previous financial years	2.23	2.23
Interest	5.00	11.85
Unused provisions + miscellaneous	–	0.72
Compensatory income	–	8.23
Supplementary income	–	4.70
	701.07	721.57

The excess income of 20.5 million Swiss francs was used as follows:

	(MCHF)
– Compensatory income used to cover expenditure not provided for in the budget (taxes, services rendered to third parties, etc. – 8.05 less balance of heading 1, 0.03)	8.02
– Supplementary income used for the $p\bar{p}$ improvement project as approved by Council	4.70
– To be used in 1985 and later for the $p\bar{p}$ improvement project	7.60
– Carried forwared to 1985	0.18
	20.50

Expenditure	*Budgets* (millions of Swiss francs)	*Accounts* (millions of Swiss francs)
	701.07	713.79

Excess expenditure amounted to 12.72 MCHF (713.79 – 701.07) and was covered by compensatory income 8.02 MCHF + 4.70 MCHF supplementary income for the $p\bar{p}$ improvement project.

Visiting Teams

The number of visiting teams' accounts increased to 350 in 1984. On 31 December, the total invoiced was approximately 19 million Swiss francs.

LEP Experiments

Consequent on the advice of the LEP Experiments Committee, CERN accepted proposals from four collaborations to provide detectors for the purpose of undertaking experiments at the LEP accelerator.

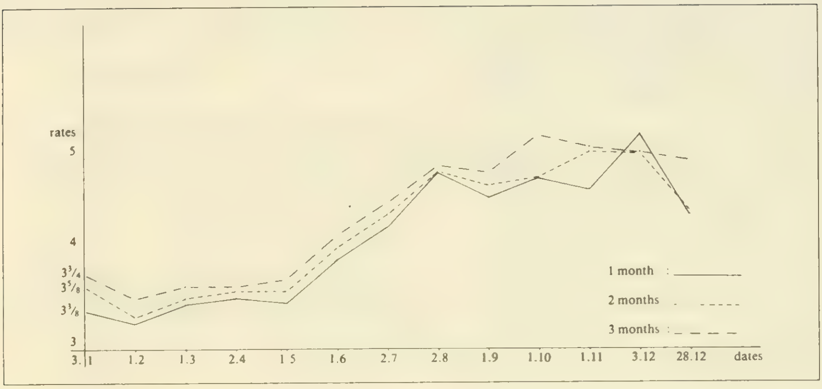
These are respectively known as the ALEPH, DELPHI, L3 and OPAL collaborations. They are very large, involving about 200 physicists on each experiment and a similar number of technical staff coming from almost every Member State and also from some ten non-Member States.

Accounts have been opened for the Common Fund items of ALEPH, DELPHI and OPAL.

On 31 December 1984, commitments, payments and balances available were as follows (in MCHF):

	Commitments	*Payments*	*Balance of funds available*
ALEPH	15.109	6.473	1.510
DELPHI	9.403	0.455	3.376
OPAL	6.059	1.465	3.022

Figure 1 — Rates of interest 1984



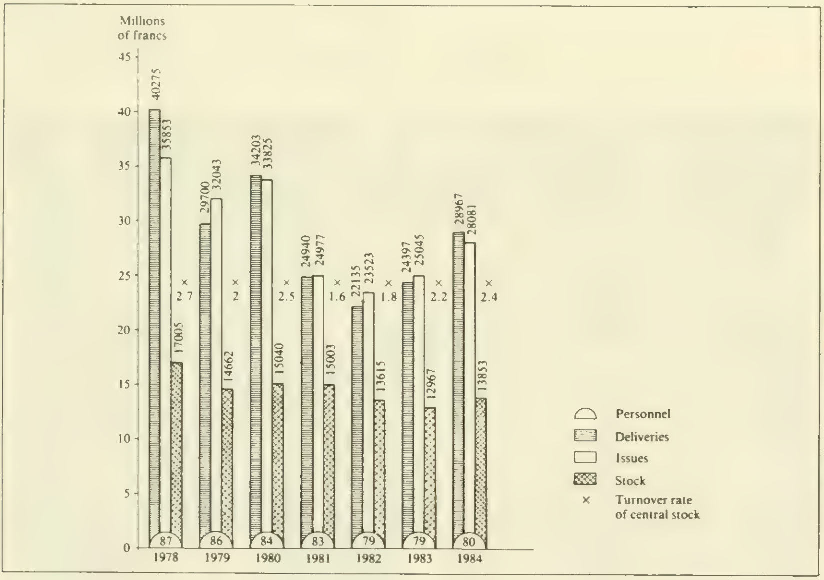
Expenditure 1984

(in thousands of Swiss francs)

Budget headings and sub-headings	Budget 1984	Expenditure 1984	Diffe-rences	Directorate-General and CIS	Research Directo-rate	Technical Directorate	LEP Project	Directorate of Admi-nistration
TOTALS	**701070**	**713796**	**+ 12726**	**30441**	**171077**	**267291**	**181932**	**63055**
1. Personnel	**342890**	**343861**	**+ 971**	**24888**	**104317**	**128680**	**39531**	**46445**
10) Staff members	321980	322918	+ 938	6059	103695	128300	39244	45620
14) Fellows	10370	10661	+ 291	10226	49	213	173	-
15) Research associates	10540	10282	– 258	8603	573	167	114	825
2. Maintenance, general expenses and consumable items	**154600**	**158481**	**+ 3881**	**5475**	**32424**	**98050**	**8517**	**14015**
20) Site and buildings	18000	18850	+ 850	16	1419	16270	661	484
21) Service equipment	15650	16567	+ 917	19	2597	9756	1526	2669
22) Equipment for accelerators and beams	22920	25479	+ 2559	-	864	21995	2559	61
23) Experimental equipment	7310	7382	+ 72	-	7027	252	83	20
25) Data handling equipment	16020	14453	– 1567	45	12445	296	723	944
27) Power and water	49250	46729	– 2521	-	-	46729	-	-
28) Administration/Consultants	21230	23608	+ 2378	5039	5478	1741	1858	9492
29) Trips	4220	5413	+ 1193	356	2594	1011	1107	345
3. Capital outlays	**203580**	**211454**	**+ 7874**	**78**	**34336**	**40561**	**133884**	**2595**
30) Site and buildings	68350	79114	+ 10864	–	1319	3821	73671	303
31) Service equipment	9960	11897	+ 1937	42	1890	4499	3945	1521
32) Equipment for accelerators and beams	100480	88632	– 11848	-	1405	31897	55350	-
33) Experimental equipment	18480	18035	– 445	-	17850	102	83	-
35) Data handling equipment	6410	13776	+ 7366	36	11872	242	855	771

Figure 2 — Delelopment of the expenditure of the Organization

Figure 3 — Development of stock movements since 1978



Stores Service

As part of the process of standardizing electronic equipment, a seminar was organized on the Europa power supply systems, attended by 39 European manufacturers from eight CERN Member States and a leading officials from the International Electrotechnical Commission (IEC). As a result, the Technical Section was encouraged to play a more active role in the IEC.

An Olivetti M40 computer and a XEROX 2700 laser printer were installed in the Distribution Section. Its first task was to automate the procedures for importing goods into Switzerland.

The entire responsibility for the work relating to the reception of goods and their internal distribution was transferred from SB Division to the Finance Department. A considerable reduction in the cost of these operations was achieved by the negotiation of a service contract with a new firm and by the introduction of certain measures to streamline procedures.

Owing to the dismantling of the ISR, the workload of the Recuperation Service was much heavier than usual.

During the year, the total value of issues of standardized equipment was 28.08 million Swiss francs, an increase of 12% over 1983. The value of items issued via the three self-service points represented 9% of total issues. The annual rate of central stock turnover was 2.4. The stock value (central and self-service) varied between -5% and +4% of the authorized limit of 13.6 million Swiss francs, whilst the average level was 0.2% below the authorized stock limit.

During the year, delivery of 53 209 items was taken and 9 427 despatches of goods were carried out for the Organization as a whole. There were 13 221 delivery requests and orders for standardized items and 250 422 requests for equipment were processed and met from central stock.

As a result of decisions, 678 in all, taken by the Standardization Groups, 264 new items were introduced into stock and 414 were declared obsolete; 191 of the latter items, worth 129 700 Swiss francs, were handed over to the Recuperation Service.

The Quality Control Service checked the conformity of 2029 deliveries (6.4% of the articles ordered worth approximately 5.4 million Swiss francs).

The Recuperation Service sold equipment outside the Organization for approximately 1.6 million Swiss francs (this included 3154 tons of scrap metal and 289 tons of scrap paper).

Management Information Department

The Management Information Department has three groups whose work clearly reflects their main purposes.

The Forecasts and Statistics Group prepares the Organization's budget, calculates the cost variation indices and the contributions from the Member States, draws up the short and long-term financial and staff requirements, and acquires and analyses the data characterising the Organization's activities and resources.

The Data-Processing Group provides the computer services for the Laboratory's administrative units including those located in the Research and Technical Divisions.

The Technical Support Group is responsible for various tasks in the fields of manpower planning, administrative procedures and micro-data-processing applied to management. It also makes specific studies for the Organization's management.

The most important achievements of 1984 relate to the following fields.

Management Facilities

The processing capacity of the central computer was increased to provide users with facilities for decentralized acquisition and for the transfer of their management data to peripheral systems, and a service which is better suited to their working environment.

The. old system of data acquisition on cassettes was abolished and replaced by on-line transactions, thus making far easier operation and saving a great deal of users' time.

Figure 1 — Meeting of the MI Technical Committee. (CERN-135.03.1985)

The COPICS software package for purchasing management became operational and several purchasing offices are now connected to it.

New facilities continue to be developed; thus LEP contract data are periodically extracted from the COPICS files and forwarded to the LEP Division. The methods for making COPICS compatible with the existing financial data base were defined, and a new procedure for monitoring contracts was drawn up and implemented with the active help of the Finance Department.

The Department was made responsible for monitoring the co-ordination and application of the rules for the use of industrial support. It worked on making procedures in this field uniform and on defining and setting up, in close collaboration with the Finance and Personnel Departments, a software package for managing industrial support facilities providing for continuous monitoring.

A computerised model for forecasting medium- and long-term personnel costs was developed and set up. It has already proved its usefulness in drawing up a financial policy for these costs.

MI also set up computerised facilities for producing:

- VAT statements of account for the French tax authorities;
- multi-annual statements of account for the LEP experiments;
- accounting balance sheets in the original currency.

Moreover, it takes part in the work of internal committees relating, in particular, to:

- procedures for admission to CERN,
- the status of firms permanently on the site,
- staff policy.

The Department also technically co-ordinates the erection of buildings 32 and 33, and is responsible for the financial management of the Administration Departments.

Management Information

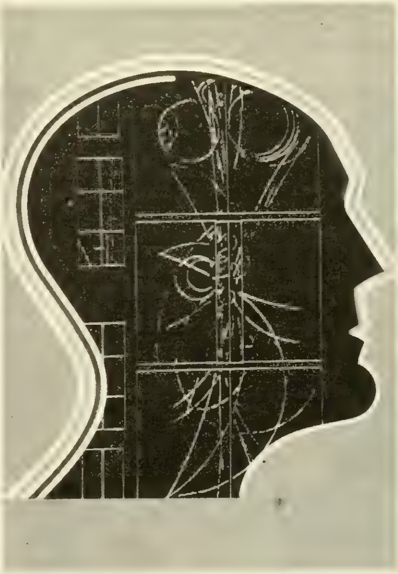
With the help of the Departments and Divisions, MI published the first 'CERN Social Report' providing collected information on working conditions. While originally intended for CERN's staff and users, it has also been distributed on request in the Member States. Its periodic updates will thus provide a reference for the assessment of the Organization's staff policy.

At the request of the Finance Committee, an examination has been undertaken of the methods used to calculate the scale of contributions, the statistical bases used and the consequences of the choices made. Alternative scales have been investigated in order to bring to light a number of other possible methods of deciding on contributions under the provisions of the Convention.

As part of the annual review of CERN's activities, a large contribution was made to the drafting of the document on 'Scientific activities and budget estimates 1985–1988' on the basis of the systems adopted by the decision-making authorities.

The critical analysis of the use made of management information which began in 1983, continued in 1984. It has resulted in the elimination of two computerised applications and in a saving of over 100000 photocopies of computer print-out pages.

Figure 2 — CERN's first Social Report is published. This illustrated bilingual document gives statistics and comments on the various facets of relations between the Organization and its personnel and on the work of some services, international relations, public relations and the staff's cultural and sporting activities.



A number of steps was taken and various projects completed with the active assistance of the Departments/Divisions concerned with the aim of facilitating the use of the management information provided. The projects included:
- the adaptation of certain accounting codes to the requirements of the construction of LEP and of the financial services;
- a new layout for the Organization's monthly management reports, which are now updated and produced using a micro-computer.

Procedures

At the request of the Management and the auditors, an examination was made of the delegation of signature rights within the Organization, and a computerised procedure for facilitating the monitoring and updating of the list of authorized signatories was set up.

The Department has published a document defining the procedures for access to the CERN site to be followed by persons not belonging to the Organization but working on the site.

In close collaboration with the Finance Department, the procedures for registering banking and postal data were simplified and a method developed for updating them on-line.

Developments

The first phase in the financial and budget data base project has been completed. It is now possible to transfer information to a data base designed for on-line interrogation. One of the important features of the data base is that it will continuously provide exact statuses meeting the requirements of both the financial services and those in charge of financial planning in the Divisions.

Another major project is now under way: the replacement of the salary appiication and the introduction of a personnel management system for which MI has acquired a software package designed to meet the Laboratory's requirements.

An 'intelligent concentrator' has been ordered to provide, via the Index network, duly authorized persons with selective access to the administrative data processing centre. Studies have begun in the field of decision-making assistance, which should result in the provision of facilities for access to data and their processing without any special knowledge.

Personnel Department

Recruitment

Following the approval of the ACOL project, 32 extra staff on fixed-term contracts were appointed during the first half of the year. Overall, some 3500 employment applications were received and processed, and some 600 candidates were invited to 100 selection boards. During 1984 there were 138 new starters, who were aged between 19 and 43 (average age : 29). The nationality distribution was as follows: Austria (1), Belgium (7), Denmark (9), France (28), Great-Britain (32), Italy (18), Federal Republic of Germany (12), the Netherlands (8), Norway (2), Spain (3), Sweden (10), Switzerland (6), non-Member States (2).

Fellowships

They increased slightly to 135, with the emphasis on the promotion of accelerator research and development. The new openings also enabled a fair number of Fellows to be appointed from Spain. The number of Associates paid by CERN (some 180 man-years) remained essentially the same as in 1983.

Unpaid Associates

Their registrations continued to increase, though at a slower rate for Member State nationals. The total reached 3300 by the end of the year.

Technical Students

The discussions on broadening the basis of this programme have led to a redefinition of its framework, allowing for increased contacts with Member State institutions concerned with training technicians and engineers. The total number of Students remained at approximately the same level as in recent years.

Housing and Installation

In order to cope with the demand of the new members of the personnel mentioned above, accommodation was found on the local market for over 500 families (including the limited number of CERN furnished flats). The continuing housing crisis in the Geneva area prompted a study of possible projects to satisfy the needs of CERN's users community. The rate of occupation of the new CERN hostel exceeded 75%. Additional facilities were introduced at the CERN hostel, notably by the provision of television lounges, a kitchen and furniture for the terrace. Some 230 removals to and from CERN were financed by the Organization.

Staff Review

370 posts were examined, of which 97 were classified at the next higher grade, and 7 cases of change of category were approved by the Senior Technical and Administrative Assistants' Committee. There were 24 appeals concerning classification and non-promotion, following which four promotions were granted and in another 7 cases the posts were classified at the next higher grade.

Consultative Committee on Employment Conditions ('CCEC')

Members of the Department made significant contributions to the review of CERN salaries, conducted by a Sub-group set up by the Standing Concertation Committee, and presented a report to the tripartite CCEC. The Department provided secretariat services to this body and participated in the preparation of other CCEC documents concerning the pension rights of shift workers, the fourth step in the complementary scheme of CERN pensions, and the CERN salary index award for 1985. Progress was made in a review of the texts of the Staff Rules and Regulations, which will in due course also be presented to CCEC.

Social Work

The section participated in a working group to study the policy relating to alcohol abuse that is applied in various organizations outside CERN. Certain recommendations of the resulting report have been adopted and will be implemented in 1985. In addition to work on individual cases, the Social Work Section initiated legislative changes in health insurance provisions concerning members of the family, divorcees and retired staff. The Section also furthered its experience of the integration into Host State social

Figure 1 — The Conference Room of the Domaine de Choully during an Active Reading Workshop directed by Pierre Artigues. This is one of the many courses within the Management Training and Personal Skills Development Programme. (CERN—074.01.1985).

security schemes of adult handicapped children and of the transition of adult children in general from their international status to a national one.

Staff Policy

The Director-General's Working Group responsible for formulating and implementing Staff Policy received considerable assistance from Personnel Department in the consideration of several important topics, including senior staff promotions, early departures, career profiles, and periodic review discussions between supervisors and their staff.

The Second CERN Utility Study

Co-ordinated by a member of the Personnel Department, the study has been completed and will be published as a Yellow Report. The main findings were that during the period 1973-1987, the 'economic utility' experienced by 160 randomly-selected European suppliers (i.e. the increased sales and cost savings due to CERN contracts) was estimated to be worth over 3100 million Swiss francs, compared to sales to CERN amounting to some 750 million Swiss francs. These findings complement an earlier study made ten years ago.

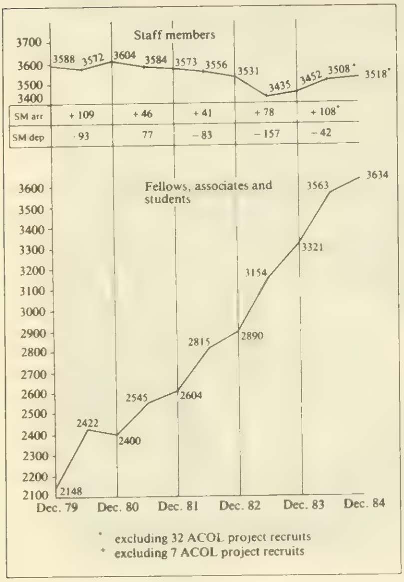
Technical Training

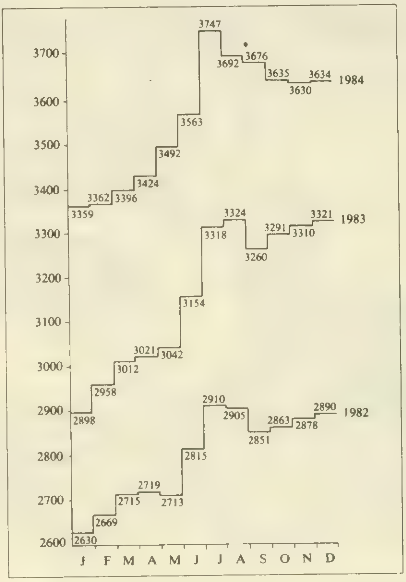
The programme was expanded to include a number of new subjects such as 'High-power electronics'; 'Laplace transform'; 'Fourier analysis'; 'Introduction to differential and integral calculus' 'Local area networks'; 'Fibre optics'; 'Introduction to numerical control of machine tools'; 'Work contracts at CERN', which are taught by means of technical seminars last-

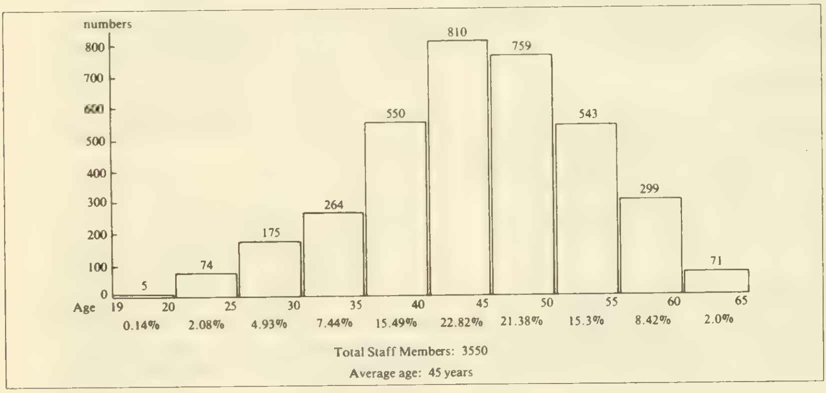
Figure 2 — Monthly totals of Fellows, Associates and students with a CERN contract in 1982, 1983 and 1984.

Figure 4 — Staff members by age group, as at end 1984.

Figure 3 — Fluctuations in the number of staff members (including laboratory personnel), Fellows, Associates and students present at CERN on 31 December of the last five years (1979–1984).







ing several consecutive days. In 1984 seven such seminars took place; some of them had to be repeated several times as enrolments exceeded 300, clearly showing the need for this new part of the programme.

Personal Skills and Management Training

This programme increased to about 100 days' training in 1984, against 60 days in 1983. Some 250 staff members attended seminars of an average length of four days.

Language courses

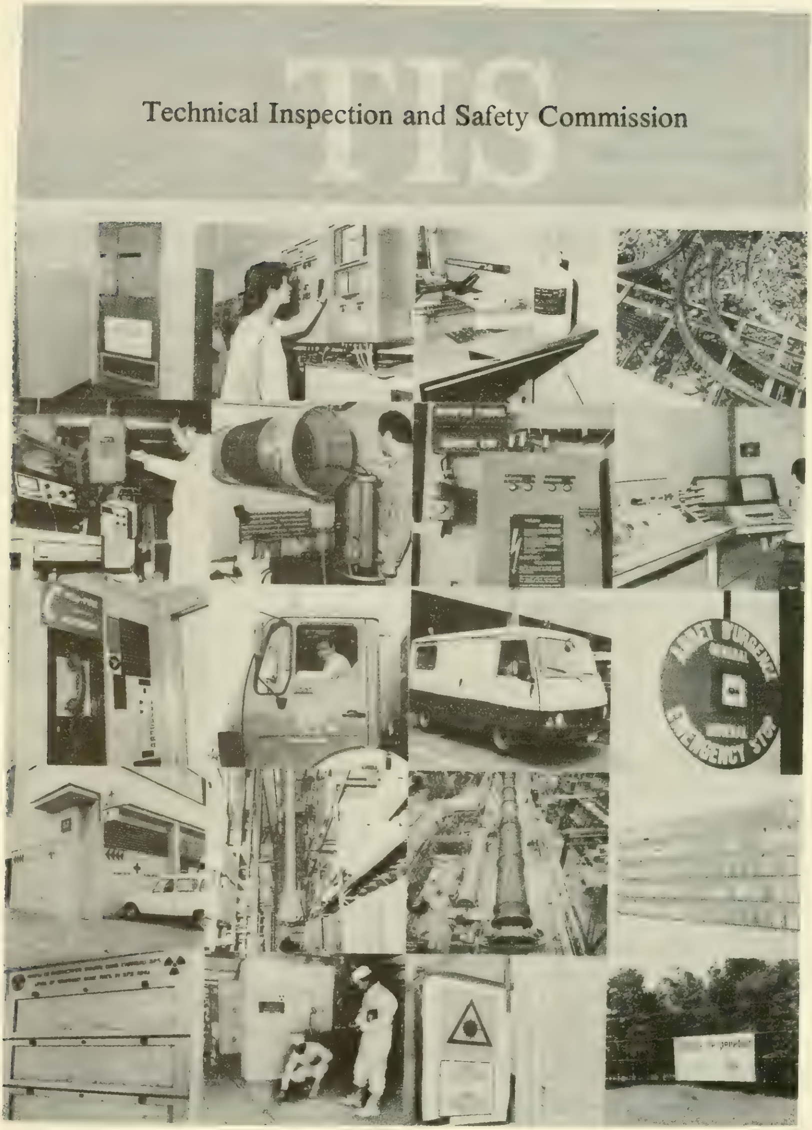
As a consequence of the sustained efforts devoted to international recruitment there was an unprecedented demand for language courses in the academic year 1984/1985. The number of new applications on 30 September 1984 compared with the same time last year showed an increase of 93% in English and 36% in French. German courses were reintroduced to satisfy a growing need for this language for work purposes.

Apprentices

The number of apprentices, which remained at 17 during the period 1971–1981, has gradually increased since then and has now almost reached its projected ceiling of 28. This scheme makes a modest contribution to vocational training in the local area.

Access control

In addition to its responsibility for controlling admission to the Meyrin site, the Reception Group took over access control for the tunnel under R.N. 84; this assignment is handled by a team supplied by a service contractor.


TIS
Technical Inspection and Safety Commission
EMERGENCY STOP

Technical Inspection and Safety Commission

This year the TIS Commission has been operating according to the programme of restructuration which was defined and adopted in 1983.

Collaboration with the different groups of the LEP Project, extending over the LEP Main Ring and the SPS and PS Divisions, has steadily improved, and the 'Hearings' on a diversified number of topics have contributed to the clarification and improvement of technical concepts in matters of safety.

The four LEP experiments involving many unconventional technical procedures—some of them never tried before—created a major challenge. The large number of contributing institutes and the fact that most of the essential components will not be designed or built at CERN created the need for co-ordination of technical standards and safety concepts in which the CERN Technical Safety Codes play an essential part. The TIS Commission has been actively engaged in contributing to technical discussions and, wherever required, in helping to organize specialized studies.

Much effort has been invested in looking into the basic fundamentals of the existing CERN Safety Codes. Amongst some of the more important codes, the Electrical and Chemical Codes were revised, and a Medical Code established with particular emphasis on the use of international standards and norms. It is hoped that the remaining codes will be revised in 1985.

The expansion of the CERN domain to accommodate the construction of LEP has triggered off an examination into how quickly our First Aid and Fire Services can act effectively within these new boundaries. Even though no definitive solution has yet been adopted, it has become clear that in view of the distances involved, a redeployment of the present First Aid and Fire Services had to be envisaged. Thus an essential saving in time between alarms and effective action could be achieved. The direct implication is the probable creation of a second station judiciously chosen on the LEP perimeter.

When the TIS Commission was set up, one of the declared aims was to bring high technical competence to the Commission—but also to place a strict time limit on the mandate of the staff concerned so as to allow them to return easily to their original activities.

Details of activities in the various TIS Groups are described below.

Road distances from the Fire-Station (Bldg. 65) to some of the points on the LEP Ring.

Lab. Prévessin	3.7 km
PA1	1 km
PA2	4.4 km
PA4	11.2 km
PA6	13.9 km
PA8	7.6 km

In the best conditions, it would take at least 15 minutes for the Fire Services to reach the top of the furthest shaft mentioned.

Electricity, Electrical Installation, and General Safety Group

Electricity and Electrical Installations

This year the new Electrical Safety Code C1 was published in a more up-to-date form.

The code is based on the most advanced international and national recommendations and standards. In addition, the appendices drawn up by specialist groups dealing with particular subjects were, or are due to be, published.

In particular, the recent Safety Instruction No. 23 entitled 'Criteria for the selection of insulating materials for electrical cables and equipment with respect to fire safety and radiation resistance' is of particular importance for the LEP installations.

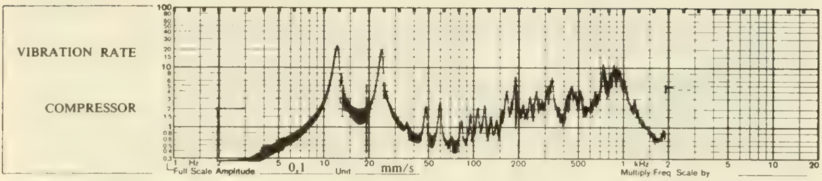
Other activities, relating to the monitoring and inspection of the different stages of project development and installation, and various training courses and safety inspections of premises, were continued. In this connection it is worth recalling that certain installations are inspected by the appropriate Host State authorities.

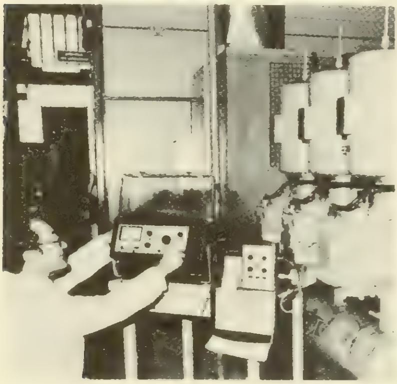
General Safety

Regular contacts were maintained with the various LEP groups responsible for installation of the machine. Particular attention was paid to communi-

Figure 1 — Vibration curve obtained from a measurement.

Figure 2 — Measurement of vibration level of a compressor. (CERN-422.01.85)





cations and alarm systems during the critical installation phase.

On the experimental side, very close contact was maintained with the experimental groups. The Group assisted with the modifications being carried out to some 15 experiments on the sites, including NA31, LEAR and UA1. In particular, the current safety studies on the UA1 experiment will be used as a reference for those carried out on the large LEP experiments.

In this respect, very effective co-operation was maintained between the Group Leaders in Matters of Safety of the four experiments ALEPH, DELPHI, OPAL, and L3 and members of the TIS Commission, through the safety meetings attended by representatives of all the groups in the experimental collaborations.

Turning to more immediate matters, the SY Group's involvement in solving personnel problems related to ergonomic conditions at the work place increased considerably. These activities, carried out in liaison with the Medical Service, were concerned with noise, ambient temperatures, vibration, lighting, and sight in general (in this regard, it should be noted that some 2000 VDU are now in use at CERN).

These problems must be given consideration in view of their impact on the quality and efficiency of work in all Divisions, whether scientific, technical, or administrative.

Finally, the overall statistics of accidents reported to the Commission for the period 1.11.1983 to 31.10.1984 are given in the following summary.

Table 1 — Statistics of accidents reported at CERN for the period 1.1.1983 au 31.10.1984

Accidents reported on HS50	*Accidents entailing absence from work*	*Days lost by members of the CERN personnel*
234 involved members of the CERN personnel (staff members and non-established members of the personnel) 55 involved contract personnel	(Including accidents occuring on the journey to and from work) 96 involved members of the CERN personnel 28 involved contract personnel	Including 7500 days (based on the ILO procedure now in force) for a death which occured on the homeward journey from work
289	124	9189

The TIS Commission is in the process of reviewing its method of calculating the frequency rate and the severity rate to take account of the total number of accidents reported (whether on HS50 or not) and of the widely fluctuating numbers of personnel on the site. This explains why the table does not give values for the period in question.

Fire Prevention and Fire Brigade

Fire Prevention Service

There was a considerable increase in the workload of the Fire Prevention Service. A direct correlation was noted between the General Safety Group's reports on conditions found and the detection of fire hazards by the Service during its inspection of work sites, and close co-operation between the two services was therefore established. The numbers of visits made and plans examined are as follows:

– Safety inspections relating to the prevention of fires or other hazards		129
– Acceptance tests for:	fire-detection systems	25
	gas-detection systems	6
	safety equipment	7
	emergency stops	4
– Fire tests (reactions of the extinguishing substances and products of fixed devices as part of the LEP fire prevention programme)		18
– Examination of LEP plans		128
– Examination of plans		7

Fire Brigade

Organization

The programme defined in 1983 which relates in particular to emergency calls (fire, flooding, medical assistance, etc.) was implemented as follows:

- Purchase of new equipment: A heavy-duty fire-fighting vehicle for LEP; A rescue cabin for the LEP shafts; An all-terrain ambulance for the LEP site; Various tools and other items of rescue equipment.

- Occupational training: In addition to the twenty days of practical training sessions organized for the five teams, various training or advanced instruction courses were arranged for ambulance men and drivers of heavy vehicles, as well as courses in welding, typing, and languages. In addition, two new firemen attended the training course at the Ecole des Recrues of the Geneva Fire and Rescue Service for six months. This year particular attention was paid to the skills required for underground rescue, such as descending in rappels, potholing techniques, and the use of high-volume foam extinguishers.

Emergency Calls

Following the introduction of new measures and in particular the decision to discontinue duties not directly associated with fire brigade activities (Security Service, tunnel customs post duty, responsibility for the keys and locks on the CERN site and their maintenance, etc.), the immediate availability of the firemen on duty increased.

During the year, the Fire Brigade's tasks included:

– Gas alarms	125
– Various alarms	72
– Fire alarms (genuine or unfounded)	415
– Fires in progress	25
– Ambulance service, including 228 internal calls and 190 external calls from the Host States	418
– Pumping and handling various spilt liquids (water, mercury, etc.)	149
– Releasing jammed lifts or goods-lifts (including 38 calls to release trapped persons)	81
– Destruction of wasps' nests	60
– Other calls for assistance	143
TOTAL	1488

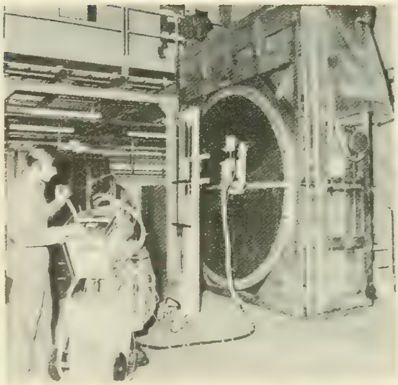
Flammable Gas and Chemistry Group

General

The Chemical Safety Code has been completely rewritten and submitted to SAPOCO for acceptance. Safety Instructions have been prepared for beryllium and for polychlorinated biphenyls (PCB).

Help has continued to be given to physics and engineering groups working with materials presenting certain hazards, such as lead, asbestos, trimethylamine, and mercury. Once more, the waste disposal service offered by the group continued to expand, and about 30 tons of used solvants and more than 100 tons of aqueous solutions of acids, alkalis, photographic products, etc., were sent for recuperation or destruction by the appropriate authorities. Silver was recovered from photographic fixing solutions collected on the site. Investigations were made into smoke density and toxic and corrosive gas emissions from burning plastics, with particular reference to LEP conditions.

Figure 3 — Inspection of the Pisa INFN liquid-argon calorimeter for exp. NA31 by means of the new portable X-ray apparatus. (CERN-188.12.1984)



Environmental Monitoring

The quality of water discharged into local rivers was monitored, and regular visits were paid to the rivers themselves to ensure their continued well-being. In parallel with action by national authorities, additional inspections were made of the discharges from the LEP work sites; this was done at the request of the LEP Division.

On the LEP Ring the two monitoring stations for ozone and oxides of nitrogen were brought into service.

Personnel Monitoring

This continued to be an important part of the work of the Group. In particular, monitoring was carried out in cleaning shops where perchloroethylene vapours constitute a hazard.

Ozone levels were measured when welding aluminium bus bars for LEP magnets, and various respiratory protective masks were tested for effectiveness.

Training

The group continued to participate in the Safety Briefing organized monthly for newcomers to CERN. Specific courses were given in chemical and flammable gas safety.

Mechanical Engineering Group

The Mechanical Engineering Group has provided technical support to the steadily growing CERN accelerator and experimental programmes in the following ways:

- advice on safety, soundness of design, reliability and economy of new equipment at the design and specification stage;
- inspections during fabrication and acceptance tests;
- periodic inspection and testing of existing equipment;
- training and licensing personnel for the use of lifting equipment.

Oral advice and instructions have been given on numerous occasions, and more than 150 assessment reports on new projects or important modifications to existing equipment have been prepared. Most of the assessment studies concerned pressure or vacuum vessels, cryostats, lifting equipment, electromechanically operated heavy devices, monorails, and other means of transport and installation.

The LEP machine and infrastructure, the four LEP experiments, and the SPS accelerator and experiments have been the most important users of our services in 1984. Worth mentioning are some critical components of the LEP experiments: the superconducting magnet cryostats for ALEPH and DELPHI; the magnet yoke structure for L3; the central detector vessel for OPAL.

Inspections and tests were carried out on many pieces of apparatus, both at CERN and on the premises of the manufacturer. In particular this was done in all cases where national inspection authorities were unable to carry out the normal inspection and certification activities because of the special nature and unusual design of the equipment. Experiment NA31 at the SPS offers a number of typical examples of such cases: the 400 m^3 vacuum tank and its 2.4 m diameter, 0.8 mm thick, composite material window, the liquid-argon calorimeter.

The design of a multipurpose overpressure test facility for vacuum vessels has been started. It will make use of recuperated components from dismantled CERN facilities.

Table 2 shows the number of periodic inspections which were carried out at CERN. This work is growing year after year as a result of the increasing complexity of activities and equipment in the laboratory.

Some of the existing CERN Safety Codes in the field of mechanical engineering need to be revised and updated. Studies have been undertaken regarding the safety of glass windows and composite materials in view of the imminent revision of the CERN Pressure Vessel Code.

In the field of training, the Mechanical Engineering Group has organized a series of courses, run by Host States authorities, on the use of cranes. These courses became necessary owing to a number of incidents with lifting equipment; they were attended by 270 CERN staff and 30 persons from industrial support labour.

Table 2 — Number of routine inspections and tests carried out in 1984

Large lifting equipment (cranes, etc.)	562
Small lifting equipment (winches, hoists, etc.)	794
Large lifting accessories	1167
Small lifting accessories	18020
Lifts	243
Other means of transport	219
Automatically closing doors	179
Industrial pressure vessels	435
Experimental pressure vessels	335
Safety valves	2862
Chimneys	11
Radiographic inspections	162
Welders' examinations	36

Medical Service

Regular Activities

The Medical Service's regular activities continued at a steady rate during 1984. This may be illustrated by the following statistics and other information:

2200 medical examinations were carried out, some 200 fewer than in 1983, but the rate of failure to attend appointments was still high (12%).

Owing to the coming into force on 1.1.1984 of the new provisions of the Radiation Safety Manual, a significant proportion of the examinations related to personnel classified as ATC (fit to work in controlled areas). None of the 450 persons examined were found to be medically unfit for such work.

Supplementary examinations were also performed to help doctors determine more precisely the fitness for work of the personnel examined. Unfortunately, attendance at several series of these examinations was very poor, since although some 7300 appointments for haematological examinations were notified to the staff, only 4300 examinations were in fact carried out. The resulting administrative and monitoring difficulties may readily be imagined.

Some 4161 persons, slightly more than in 1983, called at the Infirmary for *First Aid* treatment for illness or injury, for various types of therapy prescribed by their doctors or for examinations such as blood-pressure check-ups.

Visits to work stations were continued. The 98 visits to various locations around the site provided a better insight into the problems of work organization, ergonomics and industrial hygiene.

Special Activities

Several noteworthy activities were carried out during the year.

The transfer of *medical records on to microfilm* was begun, and 1800 records comprising some 28000 different items were stored on microfilm in fireproof cabinets. It should be noted that at the end of 1984, the Medical Service had more than 16000 medical records on file (currently employed personnel or personnel who have left the Organization, including Research Associates and contract personnel).

Important features of the Service's activities during the year were its participation in the inquiry into *alcoholism* at the work place, and the drawing-up of reports on this subject. The Medical Service will play an active role in the work of the subgroup which was set up at the end of 1984 to study possible solutions to this and related problems.

The Medical Service's *computerized data base* was adapted during the year to ensure greater efficiency, especially with regard to archive records, and new information, such as the results of the audiometric and electrocardiographic examinations could gradually be introduced. Overall, the Service currently handles some 110000 records in the form of computerized data, 17000 of them representing the identification records of all the persons on the Medical Service's files. In addition, there are some 135000 archive records on tapes, to which direct access is not available.

Following the offer of *thoracic X-rays* to the personnel, 1200 examinations were arranged. Some 20 persons were subsequently requested to undergo further examination.

The Service's doctors had to devote a considerable amount of attention and working time to a number of cases of serious psychological disorders.

Lastly, it should be noted that during the year TIS drew up and SAPOCO approved a new Medical Code, which now awaits final approval by the Director-General.

Radiation Protection Group

The Radiation Protection Group (RP) was much involved in designing radiation protection systems for new projects, in addition to coping with the important radiation protection work at all installations on the present CERN site. The radiation protection work for LEP is described separately in the LEP Progress Report.

Radiation Control of Accelerators

About half of the PS operation time was used to produce antiprotons for $p\bar{p}$ collision experiments in the SPS, for fixed-target physics in the ISR with antiprotons, and for the LEAR experiments. New records for the proton intensity on the antiproton target were reached. The RP problems connected with target maintenance and development and with beam dump-

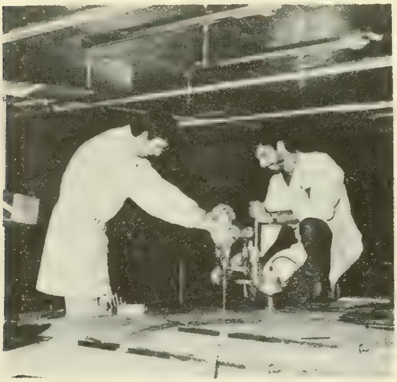


Figure 4 — Samples taken in the SFM intermagnet gap for a radioactivity check before dismantling. (CERN-195.10.84)

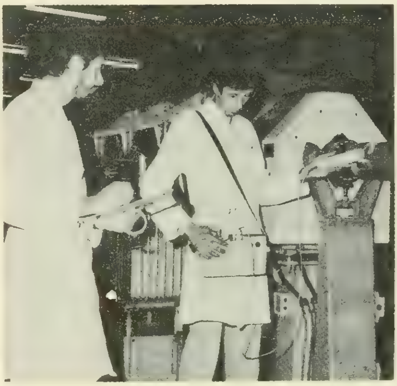


Figure 5 — Last radiation survey before the dismantling of the ISR. (CERN-192.10.84)

ing increased accordingly. The PS section of the RP Group was also involved in the LIL and EPA pre-injector project for LEP and in the design of ACOL shielding, as well as the access ways and the layout of the new antiproton target area, and in the project for a new PS access system and full-intensity beam dumps.

At the SC, besides the routine operation, the new ISOLDE project was followed very closely, as openings had to be made into the main SC shield.

The RP was heavily involved in the decommissioning of the ISR. All equipment was checked for radioactivity and sorted for storage and disposal accordingly. Magnets and vacuum pumps were stored in sector 3, where ambient activity from beam-dumping operations is the highest. Large quantities of equipment were eliminated as inactive material and only about 3–5% of the items were stored in the active storage area.

The very low personal doses registered (all below 0.5 mSv/month) and the smooth and fast sorting of material can be attributed to excellent planning and follow-up. Radiation protection coverage of the entire work was helped by good collaboration with the Transport Service. Most RP activities in the West Hall are concentrated on the LEP project or on the tests for LEP experiments.

Radiation protection of the numerous test beams, and special access and operational conditions, required close control and a large number of interventions and measurements. The same applies to the radio-

Figure 6 — Radiation control before the departure of a lorry transporting radioactive waste. (CERN-196.10.84)

Figure 7 — Volume reduction of part of the former PS neutrino tunnel, the radioactivity of which is very low after many years of decay, in order to liberate space for the new storage building. (CERN-341.04.84)

frequency test area, where klystrons and cavities are installed in a full-size LEP layout.

The underground neutrino target area operated for the last time with the narrow-band beam, creating high-radiation levels in the cave. The proposed upgrading of the area called for much attention on the part of RP when planning and assessing the dose commitment of this work in high-radiation areas.

The SPS operated until summer with fixed targets. The follow-up of the preparatory work and the operation of the primary and the very intense secondary beams resulted in a lot of work for the SPS section. Problems were encountered in controlling the primary beam and the work in beam areas. The radiation monitor system proved indispensable for giving warning when beams are out of control, and for estimating radiation levels in unexpected situations.

The RP had to survey work on radioactive equipment in the test areas, and in areas where X-ray-producing equipment is used.

For $p\bar{p}$ operation the beam loss monitor system, under the responsibility of RP, becomes more and more important as a means of guaranteeing 'clean' operation with the steadily increasing beam intensities.

Site Surveillance and Control

The volume reduction of radioactive scrap from decommissioned areas such as the former PS neutrino tunnel was an important part of the activities of the SC Site section. As well as breaking up by flame cutting, also a 90 t press was used for volume reduction. The construction of a new storage building for radioactive items started this year and preparatory work for a further storage building is well advanced. A considerable amount of slightly radioactive material resulting from the decommissioned ISR had to be taken care of.

The site survey network using thermoluminescence dosimeters now also includes 10 positions selected for pre-operational monitoring of the LEP site on Swiss territory, where measurements are carried out in collaboration with the Swiss authorities. The control of uranium, radioactive sources, and non-ionizing radiation (lasers, radio frequency, and microwaves) continued.

Environmental Monitoring

Radiation levels were measured along the CERN fences and were found to be similar to those measured in 1983, and everywhere below the CERN reference level of 1.5 mSv/year. These measurements, and the results of laboratory measurements of radioactivity in different samples of release water and aerosol, and from samples of vegetation and mud collected at the CERN periphery, were communicated quarterly to the host country authorities. No significant activity was detected.

Personnel Monitoring

Personnel exposure remained at the same level as in the preceding year. The programme for the implementation of a dose data-handling system with direct access to the ND-100 computer is on schedule. Progress was made in applying methods to suppress fading in neutron films. Because of the promising results, two-monthly distribution of neutron films will be made in 1985 for some of the less exposed staff.

In 1984 the CERN film badge service was recognized as a service which fulfils the new technical requirements for a personnel dosimetry service in Switzerland.

Technical Support

Work was started to replace the electronics for the PS and SPS radiation monitor systems, which have been operating for almost 10 years.

A local area network has been installed in order to connect various radiation protection equipment to the central RP data-acquisition system. An interface has been built to link the RP computer to the densitometer for personnel dosimeter evaluation (films). The facilities for evaluation, maintenance, and calibration of RP instruments has been improved. The NOTIS word-processing system has been implemented on the RP computer, with links to DOC and PS.

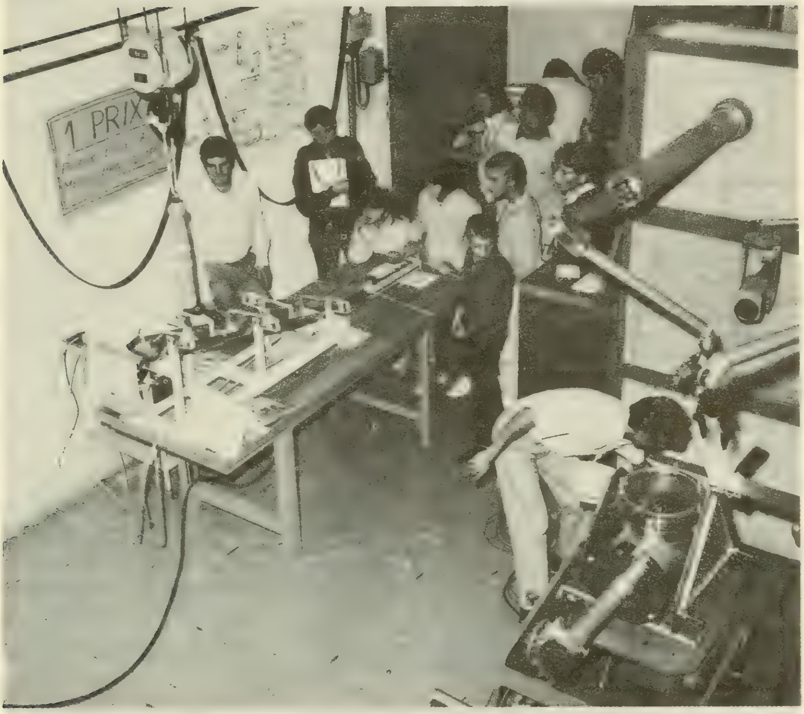
General Activities

The testing of materials to be used in radiation areas continued, as well as the long-term CERN-wide high-level dosimetry programme. Some of this work was made in close collaboration with European industry, and a number of common reports were issued. The RP staff also participated in international working groups on endurance tests and test norms.

The development of computer codes for hadron-meson cascades continued with the help of visitors from European universities. The members of RP collaborated with and took part in international working groups on dosimetry problems, on comparison of measuring methods, and on non-ionizing radiation.

The Group took an active part in the Radiation Protection Committee (topics discussed: the Antiproton Collector, the SPS as injector for LEP, and the LEP Main Ring). Discussions were held with the radiation protection authorities of the host states about new trends in personnel dosimetry for those who are only occasionally exposed.

Office and Services of the Director-General



The CERN Open Day held on 15 September once again proved to be a great success. Young people in particular were interested in discovering how certain items of equipment worked.
(CERN- 224 09.1984)

Office and Services of the Director-General

The Office and Services of the Director-General consist of the following units:
- Council Secretariat
- Public Relations
- Internal Audit
- Legal Service
- Relations with the Host States
- Scientific Conference Secretariat

Council Secretariat

During the year, the Council Secretariat made the practical arrangements for 18 Committee Meetings and 2 Council Sessions. Between 1 January and 31 December 1984, the Service co-ordinated the preparation and distribution of 174 English, 143 French, 81 German, and 23 bilingual documents.

The Secretariat also made the necessary arrangements for four Restricted and two Plenary Meetings of ECFA and prepared the relevant documents.

The Service provided the secretariat support for the holding of CERN's Thirtieth Anniversary ceremonies.

Public Relations

During the year, the Information, Press, and Visits Service was strengthened, reorganized, and renamed the Public Relations Service. A sustained effort is being made to broaden, diversify, and streamline CERN's contacts with the general public and the media.

The work of the Laboratory and the particle physics world were in the limelight as a result of the Thirtieth Anniversary of CERN and the award of the Nobel Prize for Physics to two of the Organization's physicists. As a consequence of these events and also of the increased efforts to establish closer links with the media in the Member States, contacts with the general public were considerably widened. Moreover, representatives of the local media are periodically invited to take part in discussions with the Director-General and the LEP Project Direction.

The number of visitors to the Laboratory continued to increase during the year and reached almost 20000, compared with 17000 in 1983. To this figure must be added some 4000 persons who attended the CERN Open Day held in September as part of the Thirtieth Anniversary celebrations. Various ways of coping with such large influxes of people and improving the arrangements for visits are being studied.

Appendix E lists VIPs who visited CERN in 1984.

Internal Audit

As one of its annual tasks, the Internal Audit Service checked the accounts of the Organization and the Pension Fund in accordance with the programme originally planned. However, additional checks were undertaken, in particular in response to requests from

Document statistics—Council Secretariat
1 January–31 December 1984

	Number of Documents				
	English	*French*	*German*	*Bilingual*	*Total*
Council and Committee of Council	33	33	4	5	75
Finance Committee	108	108	76	17	309
Scientific Policy Committee	13	2	1	1	17
ECFA	20	–	–	–	20
	174	143	81	23	421

the Auditors. The Service carried out a more detailed audit of the Pension Fund accounts than in the past; this served as the basis for an assessment by the Auditors, who for the first time presented a separate report on the Pension Fund.

In accordance with an agreed programme, items relating to particular services or day-to-day administration were audited. In addition, on a regular basis or by means of spot-checks, the Service monitored the application of the official regulations and procedures in force in different areas. Problems highlighted were discussed with those in charge of the areas concerned so that improvements could be introduced or corrective action taken, as necessary.

The co-ordination of auditing was improved by a certain degree of internal reorganization, which meant that day-to-day activities and a programme of work could be regularly monitored.

Legal Service

The Legal Service carried out its task as adviser to the Organization. It prepared documents and gave legal opinions on questions raised by the Director-General and the Directorate. It also maintained the necessary contacts over legal matters with the authorities of the Member States and the Host States and took part in the work of the Council and its Committees.

The Service played an active role in drawing up the documents relating to the LEP project. *Inter alia,* it gave legal opinions on and participated in the drafting of an agreement between CERN and the French authorities in view of LEP's classification as a basic nuclear installation and of documents concerning co-operation with the European Communities and the proposed European Synchrotron Radiation Facility (ESRF). It participated in various committees, in particular the Safety Policy Committee, working groups, and inquiries.

In respect of litigation, it represented the Organization's interests before national courts, managed its insurance policies, attended to the recovery of sums owed to the Organization by external debtors, and helped in the settlement of commercial disputes.

The Service also provided members of the personnel, particularly the scientific Associates, with the necessary legal guidance on such matters as legislation concerning the family, taxation, nationality, and residence.

Relations with the Host States

The Service for Relations with the Host States continued its task of representing the Organization's interests before the French and Swiss authorities at local, departmental or cantonal, and national or federal levels. It also kept in constant touch with the French and Swiss elected representatives at all levels and with numerous representative organizations.

The Service's work covered problems connected with both the LEP Project and general administrative matters.

LEP

The following activities relating to LEP were carried out:

- The Service was responsible for solving, and helped in dealing with, the administrative problems arising from the opening-up of fourteen LEP work sites, in particular with regard to:
  - access and road links,
  - land-ownership matters,
  - tips for spoil,
  - geodetic and metrological measurements,
  - supply and draining of liquids,
  - test borings, surveying and climatological studies,
  - accommodation for workers,
  - protection of the water resources in the Pays de Gex.
- Solutions were found to the social and environmental problems associated with the 14 work sites, such as disturbances caused by night work activity. In this regard, the Service acted as the channel of communication between the Management, the elected representatives, and various local bodies.
- The Service was actively involved in planning the alignments of the approximately 40 km of 18/66 kV surface power-transmission lines, and of the machine-control system (optical fibres) from the 400 kV electricity substation and the Control Room situated on the Prévessin Site, to the eight LEP access points. In this regard, the Service also established initial contacts with the relevant authorities (EDF, PTT, SNCF, national and regional authorities, and elected representatives).
- In co-operation with the appropriate authorities, the drinking-water mains in the Pays de Gex were interconnected to prevent disruption of supplies in

the event of an accident resulting from the LEP construction work.
- A substantial part of the Service's activities was associated with the construction programmes for the service roads to the access shafts and with supervision of all roadworks associated with LEP.
- The Service was responsible for the management and development of the Saint Genis–Pouilly industrial zone with a view to the establishment there of the LEP contractors.
- In association with the Commune of Gex, a caravan site for workers was set up in Gex.
- The Service took part in initiating, drawing up, and filing applications for building permits for the LEP access points with the appropriate authorities, and in following them up. The Service was also responsible for ensuring that requests for amendments to land-use and zoning regulations were submitted in due and proper form.

General Administrative Matters

The Service continued its task of managing those parts of the French site under agricutural use. Two meetings were held by the Advisory Committee set up to enable the Prefecture, locally elected representatives and representatives, of the farmers' unions to express their views on problems arising as a result of CERN's establishment in a rural area. The Committee examined and approved proposals concerning woodland conservation, hunting, and the preservation of cultivated areas.

Scientific Conference Secretariat

The Scientific Conference Secretariat organized the 1984 CERN School of Physics in Lofthus, Hardanger, Norway, and the 1984 CERN School of Computing at Aiguablava, Spain. It also assisted in the organization of the Conference on 'Teaching Modern Physics' held at CERN from 24 to 28 September 1984 (see Appendix D).

The Secretariat was also responsible for the material arrangements in connection with the CERN Colloquia, Particle Physics Seminars, and Science and Society Seminars as shown in Appendix B.

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CERN 84-02
Fassò, A; Goebel, K; Höfert, M; Rau, G; Schönbacher, H; Stevenson, G R; Sullivan, A H; Swanson, W P; Tuyn, J W N
Radiation problems in the design of the Large Electron-Positron collider (LEP)
CERN, 5 Mar 1984. - 93 p

CERN 84-03
Tröster, D A
BST - PINK PANTHER; an intelligent CAMAC crate controller
CERN, 21 Mar 1984. - 37 p

CERN 84-04
Bryant, P J
Introduction to transfer lines and circular machines
CERN, 3 Apr 1984. - 60 p
(Lectures given in the Academic Training Programme of CERN, 1983-1984)

CERN 84-05
Souverain, J
Perçages et alésages d'un tube en matériau composite Kevlar-époxy
CERN, 30 Apr 1984. - 6 p

CERN 84-06
Bernstein, J
Neutrino cosmology
CERN, 30 Apr 1984. - 73 p
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CERN 84-07
Bain, G; Bore, C; Coosemans, W; Dupont, J; Fabre, J P; Gavaggio, R; Peron, F
Automatisation par micro-ordinateur d'un instrument géodésique de mesure de distance; le distinvar
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CERN, 13 Jul 1984. - 127 p

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CERN. Geneva
Hänni, H; Schacher, J *[eds]*
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CERN, Geneva
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CERN, 5 Sep 1984. - 361 p

ECFA 84-85 v 2 ; CERN 84-10 v 2
CERN, Geneva
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CERN, 5 Sep 1984. - 240 p

CERN 84-11
Chattopadhyay, S
Some fundamental aspects of fluctuations and coherence in charged-particle beams in storage rings
CERN, 8 Oct 1984. - 155 p
(Invited contribution to the Proceedings of the 1983 Summer school on physics of high-energy particle accelerators, Upton, 6-16 Jul 1983)

CERN 84-12
Carpenter, B; Cailliau, R
Software support for Motorola 68000 microprocessor at CERN; CERN convention for programming the MC68000 family
CERN, 20 Nov 1984. - 20 p

CERN 84-13
Jacob, M; Johnsen, K
A review of accelerator and particle physics at the CERN Intersecting Storage Rings : invited talks at the last meeting of the ISR Committee, 27 Jan 1984
CERN, 30 Nov 1984. - 81 p

CERN 84-14
Bianchi-Streit, M; Blackburne, N; Budde, R; Reitz, H; Sagnell, B; Schmied, H; Schorr, B
Economic utility resulting from CERN contracts; second study
CERN, 11 Dec 1984. - 24 p

CERN 84-15
CERN. Geneva
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Hine, M G N *[ed]*
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CEC, 29 Jul 1984. - multiple pagination (EUR 9090)

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Particle accel. **16** (1984) 5-12

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Nucl. phys., B **227** (1983) 365-386

Armstrong, T; Baubillier, M; Beusch, W; Bloodworth, I J; Boca, G; Bonesini, M; Bortoletto, D; Brient, J C; Burns, A; Carney, J N; Cecchet, G; Costa, G; Evangelista, C; Ghidini, B; Kinson, J B; Lenti, V; Mandelli, L; Navach, F; Palano, A; Perini, L; Pons, Y; Quercigh, E; Strachman, Z; Tamborini, M; Worsell, M F; Zito, G; Zitoun, R
Search for new $S\bar{S}$ states in the K^- induced K^+K^- system *[Exp. no. WA60]*
Nucl. phys., B **224** (1983) 193-217

Armstrong, T A; Bloodworth, I J; Burns, A; Carney, J N; Eades, J; French, B R; Ghidini, B; Kinson, J B; Knudson, K; Lassalle, J C; Lenti, V; Mitaroff, W; Palano, A; Parrié, R; Print, I C; Quercigh, E; Shaylor, H R; Stassinaki, M; Vassiliadis, G; Votruba, M F; Zito, G; Zitoun, R
Athens - Bari - Birmingham - CERN Collaboration
Spin-parity analysis of the E meson centrally produced in the reactions $\pi^+ p \to \pi^+ (K_1^0 K^\pm K^\mp) p$ and $pp \to p(K_1^0 K^\pm \pi^\mp) p$ at 85 GeV/c *[Exp. no. WA76]*
22nd International conference on high-energy physics, Leipzig, 19-25 Jul 1984
Phys. lett., B **146** (1984) 273-278

Arneodo, M; Arvidson, A; Aubert, J J; Beaufays, J; Becks, K H; Bee, C; Benchouk, C; Bird, I; Blum, D; Böhm, E; de Bouard, X; Brasse, F W; Braun, H; Broll, C; Brown, S; Brück, H; Calen, H; Callebaut, D; Carr, J; Chima, J S; Clifft, R; Cobb, J H; Coignet, G; Combley, F; Coughlan, J; Court, G R; D'Agostini, G; Dahlgren, S; Davies, J K; Dau, W D; Dengler, F; Derado, I; Dosselli, U; Dreyer, T; Drees, J; Dumont, J J; Düren, M; Eckardt, V; Edwards, A; Edwards, M; Ernst, T; Eszes, G; Favier, J; Ferrero, M I; Figiel, J; Flauger, W; Foster, J; Gabathuler, E; Gamet, R; Gayler, J; Geddes, N; Giubellino, P; Gössling, C; Grafström, P; Grard, F; Gustafsson, L; Haas, J; Hagberg, E; Hasert, F J; Hayman, P; Heusse, P; Hoppe, C; Jaffré, M; Jacholkowska, A; Janata, F; Jancso, G; Johnson, A S; Kabuss, E M; Kellner, G; Korbel, V; Krüger, J; Kullander, S; Landgraf, U; Lanske, D; Loken, J; Long, K; Maire, M; Manz, A; Mohr, W; Montanet, F; Montgomery, H E; Mount, R P; Nagy, E; Nassalski, J; Norton, P R; Oakham, F G; Osborne, A M; Pascaud, C; Paul, L; Payre, P; Peroni, C; Pessard, H; Pettingale, J; Pietrzyk, B; Pönsgen, B; Pötsch, M; Preissner, H; Renton, P; Ribarics, P; Rith, K; Rondio, E; Schlagböhmer, A; Schmitz, N; Schneegans, M; Schröder, T; Schultze, K; Shiers, J; Sloan, T; Stier, H E; Stockhausen, W; Studt, M; Taylor, G N; Thénard, J M; Thompson, J C; de la Torre, A; Toth, J; Urban, L; Wahlen, H; Wallucks, W; Whalley, M; Wheeler, S; Williams, W S C; Williamson, J; Wimpenny, S; Windmolders, R; Wittek, W; Wolf, G; Zank, P
European Muon Collaboration: Aachen - CERN - DESY (Hamburg) - Freiburg - Hamburg (Univ.) - Kiel - LAL (Orsay) - Lancaster - LAPP (Annecy) - Liverpool - Marseille - Mons - MPI (München) - Oxford - RAL (Chilton) - Sheffield - Torino - Uppsala - Wuppertal Collaboration
Quark and diquark fragmentation into neutral strange particles as observed in muon-proton interactions at 280 GeV *[Exp. no. NA9]*
Phys. lett., B **145** (1984) 156-162

Arneodo, M; Arvidson, A; Aubert, J J; Beaufays, J; Becks, K H; Bee, C; Benchouk, C; Bird, I; Blum, D; Böhm, E; de Bouard, X; Brasse, F W; Braun, H; Broll, C; Brown, S; Brück, H; Calen, H; Callebaut, D; Carr, J; Chima, J S; Clifft, R; Cobb, J H; Coignet, G; Combley, F; Coughlan, J; Court, G R; D'Agostini, G; Dahlgren, S; Davies, J K; Dengler, F; Derado, I; Dosselli, U; Dreyer, T; Drees, J; Dumont, J J; Düren, M;

Eckardt, V; Edwards, A; Edwards, M; Ernst, T; Eszes, G; Favier, J; Ferrero, M I; Figiel, J; Flauger, W; Foster, J; Gabathuler, E; Gamet, R; Gayler, J; Geddes, N; Giubellino, P; Gössling, C; Grafström, P; Grard, F; Gustafsson, L; Haas, J; Hagberg, E; Hasert, F J; Hayman, P; Heusse, P; Hoppe, C; Jaffré, M; Jacholkowska, A; Janata, F; Jancso, G; Johnson, A S; Kabuss, E M; Kellner, G; Korbel, V; Krüger, J; Kullander, S; Landgraf, U; Lanske, D; Loken, J; Long, K; Maire, M; Manz, A; Mohr, W; Montanet, F; Montgomery, H E; Mount, R P; Nagy, E; Nassalski, J; Norton, P R; Oakham, F G; Osborne, A M; Pascaud, C; Paul, L; Pawlik, B; Payre, P; Peroni, C; Pessard, H; Pettingale, J; Pietrzyk, B; Pötsch, M; Preissner, H; Renton, P; Ribarics, P; Rith, K; Rondio, E; Schlagböhmer, A; Schmitz, N; Schneegans, M; Schröder, T; Schultze, K; Shiers, J; Sloan, T; Stier, H E; Stockhausen, W; Studt, M; Taylor, G N; Théenard, J M; Thompson, J C; de la Torre, A; Toth, J; Urban, L; Wahlen, H; Wallucks, W; Whalley, M; Wheeler, S; Williams, W S C; Wimpenny, S; Windmolders, R; Wolf, G
European Muon Collaboration: Aachen – CERN – DESY – Freiburg – Hamburg (Univ.) – Kiel – LAL (Orsay) – Lancaster – LAPP (Annecy) – Liverpool – Marseille – Mons – MPI (Munich) – Oxford – RAL (Chilton) – Sheffield – Torino – Uppsala – Wuppertal Collaboration

Transverse momentum and its compensation in current and target jets in deep inelastic muon–proton scattering *[Exp. no. NA9]*
Phys. lett., B **149** (1984) 415-420

Arnison, G; Astbury, A; Aubert, B; Bacci, C; Bauer, G; Bézaguet, A; Bock, R K; Bowcock, T J V; Calvetti, M; Carroll, T; Catz, P; Cennini, P; Centro, S; Ceradini, F; Cittolin, S; Cline, D; Cochet, C; Colas, J; Corden, M; Dallman, D; DeBeer, M; Della Negra, M; Demoulin, M; Denegri, D; Di Ciaccio, A; DiBitonto, D; Dobrzynski, L; Dowell, J D; Eggert, K; Eisenhandler, E; Ellis, N; Erhard, P; Faissner, H; Fontaine, G; Frey, R; Frühwirth, R; Garvey, J; Geer, S; Ghesquière, C; Ghez, P; Giboni, K L; Gibson, W R; Giraud-Héraud, Y; Givernaud, A; Gonidec, A; Grayer, G; Gutierrez, P; Hansl-Kozanecka, T; Haynes, W J; Hertzberger, L O; Hodges, C; Hoffmann, D; Hoffmann, H; Holthuizen, D J; Homer, R J; Honma, A; Jank, W; Jorat, G; Kalmus, P I P; Karimäki, V; Keeler, R; Kenyon, I; Kernan, A; Kinnunen, R; Kowalski, H; Kozanecki, W; Kryn, D; Kyberd, P; Lacava, F; Laugier, J P; Lees, J P; Lehmann, H; Leuchs, R; Lévêque, A; Linglin, D; Locci, E; Loret, M; Malosse, J J; Markiewicz, T; Maurin, G; McMahon, T; Mendiburu, J P; Minard, M N; Moricca, M; Muirhead, H; Muller, F; Nandi, A K; Naumann, L; Norton, A; Orkin-Lecourtois, A; Paoluzi, L; Piano Mortari, G; Pietarinen, E; Pimiä, M; Placci, A; Radermacher, E; Ransdell, J; Reithler, H; Revol, J P; Rich, J; Rijssenbeek, M; Roberts, C; Rohlf, J; Rossi, P; Rubbia, C; Sadoulet, B; Sajot, G; Salvi, G; Salvini, G; Sass, J; Saudraix, J; Savoy-Navarro, A; Schinzel, D; Scott, W; Shah, T P; Smith, D; Spiro, M; Strauss, J; Streets, J; Sumorok, K; Szoncso, F; Tao, C; Thompson, G; Timmer, J; Tscheslog, E; Tuominiemi, J; Vialle, J P; Vrana, J; Vuillemin, V; Wahl, H D; Watkins, P; Wilson, J; Xie, Y G; Yvert, M; Zurfluh, E
UA1 Collaboration: Aachen – Annecy (LAPP) – Birmingham – CERN – Helsinki – Queen Mary College London – Paris (Coll. de France) – Riverside – Rome – Rutherford Appleton Lab. – Saclay (CEN) – Vienna Collaboration

Angular distributions and structure functions from two-jet events at the CERN SPS $p\bar{p}$ collider *[Exp. no. UA1]*
Phys. lett., B **136** (1984) 294-300

Arnison, G; Allkofer, O C; Astbury, A; Aubert, B; Bacci, C; Bauer, G; Bézaguet, A; Bock, R K; Bowcock, T J V; Calvetti, M; Catz, P; Cennini, P; Centro, S; Ceradini, F; Cittolin, S; Cline, D; Cochet, C; Colas, J; Corden, M; Dallman, D; Dau, D; DeBeer, M; Della Negra, M; Demoulin, M; Denegri, D; DiBitonto, D; Di Ciaccio, A; Dobrzynski, L; Dowell, J D; Eggert, K; Eisenhandler, E; Ellis, N; Erhard, P; Faissner, H; Fincke, M; Flynn, P; Fontaine, G; Frey, R; Frühwirth, R; Garvey, J; Geer, S; Ghesquière, C; Ghez, P; Gibson, W R; Giraud-Héraud, Y; Givernaud, A; Gonidec, A; Grayer, G; Hansl-Kozanecka, T; Haynes, W J; Hertzberger, L O; Hoffmann, D; Hoffmann, H; Holthuizen, D J; Homer, R J; Honma, A; Jank, W; Jorat, G; Kalmus, P I P; Karimäki, V; Keeler, R; Kenyon, I; Kernan, A; Kinnunen, R; Kozanecki, W; Kryn, D; Kyberd, P; Lacava, F; Laugier, J P; Lees, J P; Lehmann, H; Leuchs, R; Lévêque, A; Linglin, D; Locci, E; Loret, M; Markiewicz, T; Maurin, G; McMahon, T; Mendiburu, J P; Minard, M N; Mohammadi, M; Moricca, M; Morgan, K; Muller, F; Nandi, A K; Naumann, L; Norton, A; Orkin-Lecourtois, A; Paoluzi, L; Pauss, F; Piano Mortari, G; Pietarinen, E; Pimiä, M; Pitman, D; Placci, A; Porte, J P; Radermacher, E; Ransdell, J; Reithler, H; Revol, J P; Rich, J; Rijssenbeek, M; Roberts, C; Rohlf, J; Rossi, P; Rubbia, C; Sadoulet, B; Sajot, G; Salvini, G; Sass, J; Savoy-Navarro, A; Schinzel, D; Scott, W; Shah, T P; Sheer, I; Smith, D; Strauss, J; Streets, J; Sumorok, K; Szoncso, F; Tao, C; Thompson, G; Timmer, J; Tscheslog, E; Tuominiemi, J; van Eijk, B; Vialle, J P; Vrana, J; Vuillemin, V; Wahl, H D; Watkins, P; Wilson, J; Wingerter, I; Wulz, C E; Yvert, M
UA1 Collaboration: Aachen – Annecy (LAPP) – Birmingham – CERN – Harvard – Helsinki – Kiel – Queen Mary College, London – NIKHEF, Amsterdam – Paris (Coll. de France) – Riverside – Rome – Rutherford Appleton Lab. – Saclay (CEN) – Vienna – Wisconsin Collaboration

Associated production of an isolated, large-transverse-momentum lepton (electron or muon), and two jets at the CERN $p\bar{p}$ collider *[Exp. no. UA1]*
Phys. lett., B **147** (1984) 493-508

Arnison, G; Allkofer, O C; Astbury, A; Aubert, B; Bacci, C; Bauer, G; Bézaguet, A; Bock, R K; Bowcock, T J V; Calvetti, M; Catz, P; Cennini, P; Centro, S; Ceradini, F; Cittolin, S; Cline, D; Cochet, C; Colas, J; Corden, M; Dallman, D; Dau, D; DeBeer, M; Della Negra, M; Demoulin, M; Denegri, D; DiBitonto, D; Di Ciaccio, A; Dobrzynski, L; Dowell, J; Eggert, K; Eisenhandler, E; Ellis, N; Erhard, P; Faissner, H; Fincke, M; Flynn, P; Fontaine, G; Frey, R; Frühwirth, R; Garvey, J; Geer, S; Ghesquière, C; Ghez, P; Gibson, W R; Giraud-Héraud, Y; Givernaud, A; Gonidec, A; Grayer, G; Hansl-Kozanecka, T; Haynes, W J; Hertzberger, L O; Hoffmann, D; Hoffmann, H; Holthuizen, D J; Homer, R J; Honma, A; Jank, W; Jorat, G; Kalmus, P I P; Karimäki, V; Keeler, R; Kenyon, I; Kernan, A; Kinnunen, R; Kozanecki, W; Kryn, D; Kyberd, P; Lacava, F; Laugier, J P; Lees, J P; Lehmann, H; Leuchs, R; Lévêque, A; Linglin, D; Locci, E; Loret, M; Markiewicz, T; Maurin, G; McMahon, T; Mendiburu, J P; Minard, M N; Mohammadi, M; Moricca, M; Morgan, K; Muller, F; Nandi, A K; Laumann, L;

Norton, A; Orkin-Lecourtois, A; Paoluzi, L; Pauss, F; Piano Mortari, G; Pietarinen, E; Pimiä, M; Pitman, D; Placci, A; Porte, J P; Radermacher, E; Ransdell, J; Reithler, H; Revol, J P; Rich, J; Rijssenbeek, M; Roberts, C; Rohlf, J; Rossi, P; Rubbia, C; Sadoulet, B; Sajot, G; Salvini, G; Sass, J; Savoy-Navarro, A; Schinzel, D; Scott, W; Shah, T P; Sheer, I; Smith, D; Spiro, M; Strauss, J; Streets, J; Sumorok, K; Szoncso, F; Tao, C; Thompson, G; Timmer, J; Tscheslog, E; Tuominiemi, J; Van Eijk, B; Vialle, J P; Vrana, J; Vuillemin, V; Wahl, H D; Watkins, P; Wilson, J; Wulz, C E; Yvert, M
UA1 Collaboration: Aachen – Annecy (LAPP) – Birmingham – CERN – Harvard – Helsinki – Kiel – Queen Mary College London – NIKHEF Amsterdam – Paris (Coll. de France) – Riverside – Roma – Rutherford Appleton Lab. – Saclay (CEN) – Vienna – Wisconsin Collaboration
D-production in jets at the CERN SPS collider *[Exp. no. UA1]*
Phys. lett., B **147** (1984) 222-226

Arnison, G; Allkofer, O C; Astbury, A; Aubert, B; Bauer, G; Bézaguet, A; Bock, R K; Bowcock, T J V; Calvetti, M; Catz, P; Cennini, P; Centro, S; Ceradini, F; Cittolin, S; Cline, D; Cochet, C; Colas, J; Corden, M; Dallman, D; Dau, D; DeBeer, M; Della Negra, M; Demoulin, M; Denegri, D; DiBitonto, D; Di Ciaccio, A; Dobrzynski, L: Dowell, J; Eggert, K; Eisenhandler, E; Ellis, N; Erhard, P; Faissner, H; Fincke, M; Flynn, P; Fontaine, G; Frey, R; Frühwirth, R; Garvey, J; Geer, S; Ghesquière, C; Ghez, P; Gibson, W R; Giraud-Héraud, Y; Givernaud, A; Gonidec, A; Grayer, G; Hansl-Kozanecka, T; Haynes, W J; Hertzberger, L O; Hoffmann, D; Hoffmann, H; Holthuizen, D J; Homer, R J; Honma, A; Jank, W; Jorat, G; Kalmus, P I P; Karimäki, V; Keeler, R; Kenyon, I; Kernan, A; Kinnunen, R; Kozanecki, W; Kryn, D; Kyberd, P; Lacava, F; Laugier, J P; Lees, J P; Lehmann, H; Leuchs, R; Lévêque, A; Linglin, D; Locci, E; Loret, M; Markiewicz, T; Maurin, G; McMahon, T; Mendiburu, J P; Minard, M N; Mohammadi, M; Morgan, K; Moricca, M; Muller, F; Nandi, A K; Naumann, L; Norton, A; Orkin-Lecourtois, A; Paoluzi, L; Pauss, F; Piano Mortari, G; Pietarinen, E; Pimiä, M; Pitman, D; Placci, A; Porte, J P; Radermacher, E; Ransdell, J; Reithler, H; Revol, J P; Rich, J; Rijssenbeek, M; Roberts, C; Rohlf, J; Rossi, P; Rubbia, C; Sadoulet, B; Sajot, G; Salvini, G; Sass, J; Savoy-Navarro, A; Schinzel, D; Scott, W; Shah, T P; Sheer, I; Smith, D; Strauss, J; Streets, J; Sumorok, K; Szoncso, F; Tao, C; Thompson, G; Timmer, J; Tscheslog, E; Tuominiemi, J; Van Eijk, B; Vialle, J P; Vrana, J; Vuillemin, V; Wahl, H D; Watkins, P; Wilson, J; Wulz, C E; Yvert, M
UA1 Collaboration: Aachen – Anncey (LAPP) – Birmingham – CERN – Harvard – Helsinki – Kiel – Queen Mary Coll. London – NIKHEF Amsterdam – Paris (Coll. de France) – Riverside – Rome – Rutherford Appleton Lab. – Saclay (CEN) – Vienna – Wisconsin Collaboration
Experimental observation of events with large missing transverse energy accompanied by a jet or a photon(s) in $p\bar{p}$ collisions at $\sqrt{s}$ = 540 GeV *[Exp. no. UA1]*
Phys. lett., B **139** (1984) 115-125

Arnison, G; Allkofer, O C; Astbury, A; Aubert, B; Bacci, C; Bauer, G; Bézaguet, A; Bock, R K; Bowcock, T J V; Calvetti, M; Catz, P; Cennini, P; Centro, S; Ceradini, F; Cittolin, S; Cline, D; Cochet, C; Colas, J; Corden, M; Dallman, D; Dau, D; DeBeer, M; Della Negra, M; Demoulin, M; Denegri, D; DiBitonto, D; Di Ciaccio, A; Dobrzynski, L; Dowell, J; Eggert, K; Eisenhandler, E; Ellis, N; Erhard, P; Faissner, H; Fincke, M; Flynn, P; Fontaine, G; Frey, R; Frühwirth, R; Garvey, J; Geer, S; Ghesquière, C; Ghez, P; Giboni, K L; Gibson, W R; Giraud-Héraud, Y; Givernaud, A; Gonidec, A; Grayer, G; Hansl-Kozanecka, T; Haynes, W J; Hertzberger, L O; Hoffmann, D; Hoffmann, H; Holthuizen, D J; Homer, R J; Honma, A; Jank, W; Jorat, G; Kalmus, P I P; Karimäki, V; Keeler, R; Kenyon, I; Kernan, A; Kinnunen, R; Kozanecki, W; Kryn, D; Kyberd, P; Lacava, F; Laugier, J P; Lees, J P; Lehmann, H; Leuchs, R; Lévêque, A; Linglin, D; Locci, E; Loret, M; Markiewicz, T; Maurin, G; McMahon, T; Mendiburu, J P; Minard, M N; Mohammadi, M; Moricca, M; Morgan, K; Muller, F; Nandi, A K; Naumann, L; Norton, A; Orkin-Lecourtois, A; Paoluzi, L; Pauss, F; Piano Mortari, G; Pietarinen, E; Pimiä, M; Pitman, D; Placci, A; Porte, J P; Radermacher, E; Ransdell, J; Reithler, H; Revol, J P; Rich, J; Rijssenbeek, M; Roberts, C; Rohlf, J; Rossi, P; Rubbia, C; Sadoulet, B; Sajot, G; Salvini, G; Sass, J; Savoy-Navarro, A; Schinzel, D; Scott, W; Shah, T P; Sheer, I; Smith, D; Spiro, M; Strauss, J; Streets, J; Sumorok, K; Szoncso, F; Tao, C; Thompson, G; Timmer, J; Tscheslog, E; Tuominiemi, J; Van Eijk, B; Vialle, J P; Vrana, J; Vuillemin, V; Wahl, H D; Watkins, P; Wilson, J; Wulz, C E; Yvert, M
UA1 Collaboration: Aachen – Annecy (LAPP) – Birmingham – CERN – Harvard – Helsinki – Kiel – Queen Mary College London – NIKHEF Amsterdam – Paris (Coll. de France) – Riverside – Roma – Rutherford Appleton Lab. – Saclay (CEN) – Vienna – Wisconsin Collaboration
Observation of muonic Z^0 decay at the $p\bar{p}$ collider *[Exp. no. UA1]*
Phys. lett., B **147** (1984) 241-248

Arnison, G; Astbury, A; Aubert, B; Bacci, C; Bauer, G; Bézaguet, A; Bock, R K; Bowcock, T J V; Calvetti, M; Catz, P; Cennini, P; Centro, S; Ceradini, F; Cittolin, S; Cline, D; Cochet, C; Colas, J; Corden, M; Dallman, D; Dau, D; DeBeer, M; Della Negra, M; Demoulin, M; Denegri, D; Di Ciaccio, A; DiBitonto, D; Dobrzynski, L; Dowell, J; Eggert, K; Eisenhandler, E; Ellis, N; Erhard, P; Faissner, H; Fincke, M; Fontaine, G; Frey, R; Frühwirth, R; Garvey, J; Geer, S; Ghesquière, C; Ghez, P; Giboni, K L; Gibson, W R; Giraud-Héraud, Y; Givernaud, A; Gonidec, A; Grayer, G; Hansl-Kozanecka, T; Haynes, W J; Hertzberger, L O; Hoffmann, D; Hoffmann, H; Holthuizen, D J; Homer, R J; Honma, A; Jank, W; Jorat, G; Kalmus, P I P; Karimäki, V; Keeler, R; Kenyon, I; Kernan, A; Kinnunen, R; Kozanecki, W; Kryn, D; Lacava, F; Laugier, J P; Lees, J P; Lehmann, H; Leuchs, R; Lévêque, A; Linglin, D; Locci, E; Malosse, J J; Markiewicz, T; Maurin, G; McMahon, T; Mendiburu, J P; Minard, M N; Mohammadi, M; Morgan, K; Moricca, M; Muirhead, H; Muller, F; Nandi, A K; Naumann, L; Norton, A; Orkin-Lecourtois, A; Paoluzi, L; Pauss, F; Piano Mortari, G; Pietarinen, E; Pimiä, M; Placci, A; Porte, J P; Radermacher, E; Ransdell, J; Reithler, H; Revol, J P; Rich, J; Rijssenbeek, M; Roberts, C; Rohlf, J; Rossi, P; Rubbia, C; Sadoulet, B; Sajot, G; Salvi, G; Salvini, G; Sass, J; Saudraix, J; Savoy-Navarro, A; Schinzel, D; Scott, W; Shah, T P; Smith, D; Spiro, M; Strauss, J; Streets, J; Sumorok, K; Szoncso, F; Tao, C; Thompson, G; Timmer, J; Tscheslog, E; Tuominiemi, J; Van Eijk, B; Vialle, J ;

Vrana, J; Vuillemin, V; Wahl, H D; Watkins, P; Wilson, J; Wulz, C E; Xie, Y G; Yvert, M; Zurfluh, E
UA1 Collaboration: Aachen – Annecy (LAPP) – Birmingham – CERN – Harvard – Helsinki – Queen Mary Coll. London – NIKHEF Amsterdam – Paris (Coll. de France) – Riverside – Rome – Rutherford Appleton Lab. – Saclay (CEN) – Vienna – Wisconsin Collaboration
Observation of the muonic decay of the charged intermediate vector boson *[Exp. no. UA1]*
Phys. lett., B **134** (1984) 469-476

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UA1 Collaboration: Aachen – Annecy (LAPP) – Birmingham – CERN – Helsinki – Queen Mary College London – Paris (Coll. de France) – Riverside – Rome – Rutherford Appleton Lab. – Saclay (CEN) – Vienna Collaboration
Search for massive $e\nu\gamma$ and $\mu\nu\gamma$ final states at the CERN Super Proton Synchrotron collider *[Exp. no. UA1]*
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CERN Machine Group Collaboration
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CERN Machine Group Collaboration
Large hadron collider in the LEP tunnel; a feasibility study of possible options
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Omega – Photon Collaboration: Bonn – CERN – Glasgow – Lancaster – Manchester – Paris VI – Rutherford – Sheffield Collaboration
Inclusive photoproduction of δ(980) and B(1235) at high x_F *[Exp. no. WA57]*
Phys. lett., B **138** (1984) 459-463

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Omega - Photon Collaboration: Bonn - CERN - Glasgow - Lancaster - Manchester - Paris VI - Rutherford - Sheffield Collaboration
Inclusive photoproduction of ϱ and ω in the photon energy range 20 to 70 GeV *[Exp. no. WA57]*
Nucl. phys., B **245** (1984) 189-214

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Omega - Photon Collaboration: Bonn - CERN - Glasgow - Lancaster - Manchester - Paris VI - Rutherford - Sheffield Collaboration
Observation of a peak at 1.28 GeV in the $\eta\pi\pi$ system in the reaction $\gamma p \rightarrow \eta\pi^+\pi^- p$ *[Exp. no. WA57]*
Nucl. phys., B **242** (1984) 269-281

Atkinson, M; Axon, T J; Barberis, D; Brodbeck, T J; Brookes, G R; Bunn, J J; Bussey, P J; Clegg, A B; Dainton, J B; Davenport, M; Dickinson, B; Diekmann, B; Donnachie, A; Ellison, R J; Flower, P; Flynn, P J; Galbraith, W; Heinloth, K; Henderson, R C W; Hughes-Jones, R E; Hutton, J S; Ibbotson, M; Jakob, H P; Jung, M; Kemp, M A R; Kumar, B R; Laberrigue, J; Lafferty, G D; Lane, J B; Lassalle, J C; Lévy, J M; Liebenau, V; McClatchey, R H; Mercer, D; Morris, J A G; Morris, J V; Newton, D; Paterson, C; Patrick, G N; Paul, E; Raine, C; Reidenbach, M; Rotscheidt, H; Schlösser, A; Sharp, P H; Skillicorn, I O; Smith, K M; Storr, K M; Thompson, R J; de la Vaissière, C; Waite, A P; Worsell, M F; Yiou, T P
Omega - Photon Collaboration: Bonn - CERN - Glasgow - Lancaster - Manchester - Paris VI - Rutherford - Sheffield Collaboration
Photoproduction of $K\bar{K}\pi$ final states in the photon energy range from 20 to 70 GeV *[Exp. no. WA57]*
Nucl. phys., B **231** (1984) 1-14

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Omega - Photon Collaboration: Bonn - CERN - Glasgow - Lancaster - Manchester - Paris VI - Rutherford - Sheffield Collaboration
Photoproduction of multiparticle states in the beam fragmentation region for photon energies in the range 50-70 GeV *[Exp. no. WA57]*
Z. Phys. C **26** (1984) 19-26

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Bonn - CERN - Glasgow - Lancaster - Manchester - Paris VI - Rutherford - Sheffield Collaboration: Omega - Photon Collaboration
Photoproduction of $\pi^+\pi^-\pi^0$ on hydrogen with linearly polarized photons of energy 20-70 GeV *[Exp. no. WA57]*
Nucl. phys., B **231** (1984) 15-39

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Omega - Photon Collaboration: Bonn - CERN - Glasgow - Lancaster - Manchester - Paris VI - Rutherford - Sheffield Collaboration
Photoproduction of $\varrho\varrho$ and ϱf systems *[Exp. no. WA57]*
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Atkinson, M; Axon, T J; Barberis, D; Brodbeck, T J; Brookes, G R; Bunn, J J; Bussey, P J; Clegg, A B; Dainton, J B; Davenport, M; Dickinson, B; Diekmann, B; Donnachie, A; Ellison, R J; Flower, P; Flynn, P J; Galbraith, W; Heinloth, K; Henderson, R C W; Hughes-Jones, R E; Hutton, J S; Ibbotson, M; Jakob, H P; Jung, M; Kemp, M A R; Kumar, B R; Laberrigue, J; Lafferty, G D; Lane, J B; Lassalle, J C; Lévy, J M; Liebenau, V; McClatchey, R H; Mercer, D; Morris, J A G;

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Bonn – CERN – Glasgow – Lancaster – Manchester – Paris VI – Rutherford – Sheffield Collaboration: Omega – Photon Collaboration
A spin-parity analysis of the $\omega\pi^0$ enhancement photoproduced in the energy range 20 to 70 GeV *[Exp. no. WA57]*
Nucl. phys., B **243** (1984) 1-28

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European Muon Collaboration: CERN – DESY (Hamburg) – Freiburg – Kiel – Lancaster – LAPP (Annecy) – Liverpool – Marseille – Oxford – Rutherford – Sheffield – Turin – Wuppertal Collaboration
A comparison of proton, antiproton and meson distributions in final states of deep inelastic muon scattering *[Exp. no. NA2]*
Phys. lett., B **135** (1984) 225-230

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European Muon Collaboration; CERN – DESY (Hamburg) – Freiburg – Kiel – Lancaster – LAPP (Annecy) – Liverpool – Marseille – Oxford – Rutherford – Sheffield – Turin – Wuppertal Collaboration
The measurement of Bethe-Heitler bremsstrahlung in muon-hydrogen interactions at 200 GeV *[Exp. no. NA2]*
Z. Phys. C **22** (1984) 341-344

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Proceedings, 8th International conference on magnet technology, Grenoble, 5-9 Sep 1983
J. phys., colloq. **45** (C1) (1984) C1.297-C1.300

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NA3 Collaboration: CEN Saclay – CERN – Coll. de France Paris – Ecole Polytech. Palaiseau – LAL Orsay Collaboration
Study of the low mass dimuon continuum produced in hadronic interactions *[Exp. no. NA3]*
Phys. lett., B **142** (1984) 446-450

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SU(2) symmetry breaking from QCD sum rules
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Bagnaia, P; Banner, M; Battiston, R; Bloch, P; Bonaudi, F; Borer, K; Borghini, M; Chollet, J C; Clark, A G; Conta, C; Darriulat, P; Di Lella, L; Dines-Hansen, J; Dorsaz, P A; Fayard, L; Fraternali, M; Froidevaux, D; Fumagalli, G; Gaillard, J M; Gildemeister, O; Goggi, V G; Grote, H; Hahn, B; Hänni, H; Hansen, J R; Hansen, P; Himel, T; Hungerbühler, V; Jenni, P; Kofoed-Hansen, O; Lançon, E; Livan, M; Loucatos, S; Madsen, B; Mani, P; Mansoulié, B; Mantovani, G C; Mapelli, L; Merkel, B; Mermikides, M; Møllerud, R; Nilsson, B; Onions, C; Parrour, G; Pastore, F; Plothow-Besch, H; Polverel, M; Repellin, J P; Rimoldi, A; Rothenberg, A; Roussarie, A; Sauvage, G; Schacher, J; Siegrist, J L; Steiner, H M; Stimpfl, G; Stocker, F; Teiger, J; Vercesi, V; Weidberg, A R; Zaccone, H; Zakrzewski, J A; Zeller, W
UA2 Collaboration
Evidence for $Z^0 \to e^+e^-$ at the CERN $\bar{p}p$ collider *[Exp. no. UA2]*
Phys. lett., B **129** (1983) 130-140

Bagnaia, P; Banner, M; Battiston, R; Bloch, P; Borer, K; Borghini, M; Bürger, J; Cenci, P; Chollet, J C; Clark, A G; Conta, C; Darriulat, P; Di Lella, L; Dines-Hansen, J;

Engelmann, R; Fayard, L; Fraternali, M; Froidevaux, D; Gaillard, J M; Gildemeister, O; Goggi, V G; Gössling, C; Hahn, B; Hänni, H; Hansen, J R; Hansen, P; Harnew, N; Himel, T; Jenni, P; Kofoed-Hansen, O; Lançon, E; Livan, M; Loucatos, S; Madsen, B; Mani, P; Mansoulié, B; Mantovani, G C; Mapelli, L; Merkel, B; Møllerud, R; Onions, C; Parrour, G; Pastore, F; Plothow-Besch, H; Polverel, M; Repellin, J P; Rothenberg, A; Roussarie, A; Sauvage, G; Schacher, J; Siegrist, J L; Stimpfl, G; Stocker, F; Swartz, M; Teiger, J; Tovey, S; Vercesi, V; Weidberg, A R; Zaccone, H; Zakrzewski, J A; Zeller, W
UA2 Collaboration: Bern – CERN – Copenhagen (NBI) – Orsay (LAL) – Pavia – Saclay (CEN) Collaboration
Measurement of jet fragmentation properties at the CERN $\bar{p}p$ collider *[Exp. no. UA2]*
Phys. lett., B **144** (1984) 291-296

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UA2 Collaboration: Bern – CERN – Copenhagen (NBI) – Orsay (LAL) – Pavia – Saclay (CEN) Collaboration
Measurement of jet production properties at the CERN $\bar{p}p$ collider *[Exp. no. UA2]*
Phys. lett., B **144** (1984) 283-290

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UA2 Collaboration: Bern – CERN – Copenhagen (NBI) – Orsay (LAL) – Pavia – Saclay (CEN) Collaboration
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UA2 Collaboration: Bern – CERN – Copenhagen (NBI) – Orsay (LAL) – Pavia – Saclay (CEN) Collaboration
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UA2 Collaboration: Bern – CERN – Copenhagen (NBI) – Orsay (LAL) – Pavia – Saclay (CEN) Collaboration
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ACCMOR Collaboration: Amsterdam – Bristol – CERN – Cracow – Munich – Rutherford Collaboration
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ACCMOR Collaboration: Amsterdam - Bristol - CERN - Cracow - Munich - Rutherford Collaboration
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Amsterdam - Bristol - CERN - Cracow - Munich - Rutherford Collaboration: ACCMOR Collaboration
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[Exp. no. PS169]
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Appendix B

* Seminars and Colloquia

EXPERIMENTAL PHYSICS SEMINARS

M. Chemarin (Inst. de Physique Nucléaire de Lyon) (16.1.)
Charmonium at the ISR.

H. Nowak (CERN) (23.1.)
Production of charmed lambda baryons at low energies.

J. Bürger (DESY and CERN) (30.1.)
Results on hard-scattering processes in two photon interactions at the PLUTO detector at PETRA.

G. Snow (Rockefeller University) (6.2.)
Photon diffraction dissociation in a high-pressure hydrogen projection chamber.

P.B. Price (CERN and Univ. of California at Berkeley) (20.2.)
Searches for GUT monopoles at a flux below the Parker limit.

T. Lohse (Dortmund University) (27.2.)
Production of high-transverse-momentum baryons and mesons in deep inelastic hadronic interactions at the ISR.

M. Marx (SUNY, Stony Brook) (2.3.)
The D0 project – Physics at 2 TeV.

A. Blondel (CERN, and École Polytechnique, Palaiseau) (5.3.)
Performance of a ring-imaging water Cherenkov prototype.

N. Wermes (SLAC) (12.3.)
Results on glueball searches and D physics from MARK III.

M. Heiden (CERN) (19.3.)
Study of charmed particle production at the Split Field Magnet detector.

P. Böckmann (CERN) (2.4.)
Results from ARGUS at PETRA.

C. von Gagern (Rockefeller University) (9.4.)
Studies of high-p_T and E_T^0 phenomena in $p\bar{p}$ and pp interactions at the ISR.

L. Gatignon (CERN) (16.4.)
Inclusive meson production in K^+p interactions at 70 GeV/c.

R. Brun (CERN) (21.5.)
First results on CHARM from NA27.

G. Herten (CERN) (4.6.)
Recent results from MARK-J.

H.J. Burckhart (CERN) (13.6.)
Observation of the charmed strange baryon A^+.

K. Freudenreich (CERN) (18.6.)
Observation of scaling violations in the hadronic production of high-mass dimuons.

A. Peisert (MPI, Munich, and CERN) (25.6.)
Results on the ALEPH model TPC: the TPC 90.

S. Lloyd (Oxford University) (2.7.)
Latest TASSO results on the fragmentation of charm and bottom quarks.

P. Steffen (CERN and DESY) (16.7.)
Determination of the B lifetime.

K. Wendt (Mainz University and CERN) (13.8.)
Laser spectroscopy at ISOLDE: The study of nuclear properties far off stability.

R. Wilson (SLAC) (27.8.)
ASP: a new PEP detector to search for single photons.

E. Lançon (Saclay) (10.9.)
Inclusive particle production in UA2 at the $Sp\bar{p}S$ collider.

A. Palano (Dept. of Physics and INFN, Bari) (17.9.)
Observation of the E meson in central production and determination of its quantum numbers.

K. Einsweiler (CERN) (22.10.)
Radiative J/ψ decays to two pseudoscalar mesons.

P. Renton (Oxford University) (5.11.)
Hadron production in 280 GeV muon–proton scattering.

T. Bolognese (DPHPE, Saclay) (12.11.)
QCD effects and non-perturbative effects in deep-inelastic neutrino and antineutrino charged-current interactions.

W. Heck (Freiburg University) (19.11.)
Large-transverse-momentum direct photon and π^0 production in π^-p, π^+p, and pp collisions at the SPS at 300 GeV/c.

H. Boerner (CERN) (3.12.)
Drift chambers and cherry blossoms—experiments at the e^+e^- collider TRISTAN in Japan.

A.C. Schaffer (Columbia University) (10.12.)
A search for like-sign dilepton production by neutrinos in the 15 ft bubble chamber.

COLLOQUIA

F. Levi (University of Perugia) (28.2.)
Galileo Galilei and experimental science.

S. Haroche (École Normale Supérieure, Paris) (8.3.)
Rydberg atoms: Atomic physics on a giant scale.

H. Sexl (Vienna University) (29.3.)
Physics in sports.

D. Kleppner (Lab. de Spectroscopie Hertzienne, Paris, and MIT, Cambridge) (10.4.)
Spin-polarized hydrogen

R. Ruffini (Rome University) (17.4.)
Galaxies: Testing ground for –inos.

M. Markus (MPI for Nutritional Physiology, Dortmund) (19.4.)
Chaotic dynamics in sugar metabolism.

W. Greiner (Johann Wolfgang Goethe Universität, Frankfurt) (22.5.)
The supercritical electric field.

W. Weidlich (Stuttgart University) (12.6.)
Concepts and models of a quantitative sociology.

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* Not published.

M. Rees (Institute of Astronomy, Cambridge) (26.6.)
Black holes: the central engine in quasars and galactic nuclei.

A. Dar (Technion, Haifa) (26.7.)
Ultrahigh energy neutrino physics and astronomy.

P. Meyer (Enrico Fermi Institute, Chicago) (11.9.)
Recent work on solar neutrons and on the helium isotopes in the galactic cosmic rays.

W.K.H. Panofsky (SLAC) (27.9.)
The SSC high-energy e^+e^- colliders and all that.

H.O. Wüster (JET) (20.11.)
The JET project: results and problems of first year of operation.

R.M. Bonnet (ESA, Paris) (4.12.)
Achievements and prospects of the European Space Agency scientific programme.

Nobel lectures (18.12.)
S. van der Meer (CERN): Stochastic cooling and the accumulation of antiprotons.
C. Rubbia (CERN): Experimental observation of the intermediate vector bosons W and Z.

SCIENCE AND SOCIETY SEMINARS

Seminar in honour of A. Sacharov's 63rd birthday (30.5.)
S.L. Glashow (Harvard University): Encounters of planet Earth with quark-matter
A. De Rújula (CERN): A singular man.

A. Rörsch (Netherlands Organization for Applied Scientific Research, The Hague) (24.9.)
The impact of genetic engineering on science and society.

W.K.H. Panofsky (SLAC) (26.9.)
East–West strategic arms race.

PARTICLE PHYSICS SEMINARS

D. Cline (University of Wisconsin, Madison) (10.1.)
Status of the search for baryon decay

B.A. Andersson (Lund University) (12.1.)
Confinement likes polarization.

R. Strub (Centre de Recherches Nucléaires, Strasbourg) (16.2.)
Study of 16000 Ω^- decays collected in the CERN SPS hyperon beam.

M. Veltman (University of Michigan) (24.2.)
Bound states of vector bosons.

A. Zichichi (CERN) (1.3.)
The end of a myth: high p_T physics.

W.T. Ford (University of Colorado, Boulder) (13.3.)
Measurement of the B lifetime with MAC at PEP.

L. Galtieri (Lawrence Berkeley Laboratory) (15.3.)
Recent results from the TPC detector at PEP.

A. Roussarie (Saclay) (20.3.)
Large mass electron–neutrino pairs from UA2.

J. Van der Velde (Orsay) (12.4.)
Latest results from the IMB proton decay detector.

F. Pauss (CERN) (26.4.)
Latest results from UA1.

W. Fetscher (ETH Zurich) (8.5.)
Determination of the muon decay parameters.

A. De Rújula (CERN) (15.5.)
Neutrino and muon physics in the collider mode of future accelerators.

Y. Declais (Centre de Physique des Particules, Marseille) (24.5.)
Indications for neutrino oscillations in the Bugey reactor experiment.

G. Altarelli (Rome University and CERN) (29.5.)
Electron–proton physics at future colliders.

B. Winstein (Enrico Fermi Institute and Dept. of Physics, University of Chicago) (19.6.)
An experimental determination of ϵ'/ϵ in the neutral kaon system.

P. Bagnaia (CERN) (21.6.)
Latest results on jets from the UA2 experiment at the CERN proton–antiproton collider.

R.F. Schwitters (Harvard University and Fermilab) (28.6.)
Plans and progress on the Tevatron collider program at Fermilab.

M. Della Negra (LAPP, Annecy and CERN) (3.7.)
Observation of isolated large-transverse-momentum leptons with two associated jets in the UA1 experiment.

K.-P. Streit (Heidelberg University) (5.7.)
New results on baryons with charm and strangeness.

D. Atkinson (University of Groningen) (14.8.)
Possible left–right symmetry and beta decay.

J. Rosner (University of Chicago) (16.6.)
Heavy neutral leptons and new range bosons: Some experimental prospects for the rest of the '80's.

E. Bloom (Stanford University) (4.9.)
Evidence for a narrow massive state in the radiative decays of the upsilon.

E.H. Bellamy (Westfield College, London) (13.9.)
Measurement of the pion form factor.

B. Foster (University of Bristol and DESY) (18.9.)
Experience and lifetime measurements with the TASSO vertex detector.

L. Pottier (Laboratoire de Spectroscopie Hertzienne de l'École Normale Supérieure, Paris) (2.10.)
Measurements of parity violation in the caesium atom: a low-q test of electroweak unification.

A.D. Krisch (University of Michigan) (4.10.)
High-transverse-momentum spin physics and the AGS polarized proton beam.

E.M. Henley (University of Washington and University of Tübingen) (11.10.)
Tests of electroweak interactions with electrons from atoms to high energies.

C.H. Llewellyn Smith (Oxford University) (13.11.)
What can we learn from the EMC effect?

R. Landua (CERN) (27.11.)
The X-ray spectrum of antiprotonic hydrogen formed in H_2 gas.

V. Zacek (Technical University, Munich) (11.12.)
Search for neutrino oscillations at the Gösgen power reactor.

COMPUTER SEMINARS

P. Stucki (IBM Zürich Research Laboratory, Rüschlikon, Switzerland) (18.1.)
The integration of text and image and its application to engineering documentation.

J. Sventek (Lawrence Berkeley Laboratory, Berkeley, USA) (4.4.)
Distributed systems research at Lawrence Berkeley Laboratory.

X3J3 Committee Members: J. Adams (Colorado State University); N. Marshall (EG&G); J. Wagener (Amoco); G. Paul (IBM Yorktown Heights) (13.4.)
FORTRAN forum

E.J. Siskind (NYCB Real-Time Computing, Port Washington, USA) (2.5.)
Future uses for FASTBUS and other data acquisition interconnections.

J.D. Bruce (Massachussets Institute of Technology, Cambridge, USA) (13.6.)
Computer networks at MIT.

A. Colmerauer (Faculté des Sciences de Luminy, Marseille, France) (20.6.)
PROLOG in 10 figures.

T.J. Killian (AT&T Bell Laboratories, Murray Hill, USA) (26.9.)
UNIX 8th edition

E. Clementi (IBM Kingston Laboratory, USA) (5.10.)
Experimenting with parallel computing.

T. Nash (Fermi National Accelerator Laboratory, Batavia, USA) (10.10.)
The ACP multiprocessor project at Fermilab.

R.F. Puk (Independent Consultant – computer graphics systems architectures) (7.12.)
Graphics standards after GKS

D.L. Nelson (Apollo Computer Inc., Chelmsford, USA) (13.12.)
Emergence of workstations.

Appendix C

*Training Programmes 1983/84

ACADEMIC TRAINING

Lecture Series (20 series: 96 lectures)

Gauge theories: basic concepts and experimental consequences
G. Altarelli (University of Rome and CERN) (6 lectures).

High-energy physics after the discovery of the W and Z particles
L. Van Hove (CERN) (4 lectures).

Monopoles
P. Musset, D. Nanopoulos (CERN) (3 lectures).

Introduction to transfer lines and circular machines
Ph. Bryant (CERN) (4 lectures).

The experimental approach to W and Z physics
P. Darriulat (CERN) (3 lectures).

Statistical error estimation
M. Roos (University of Helsinki) (6 lectures).

Traitement thermomécaniques des alliages.
Effets sur les propriétés mécaniques
W. Benoit, B. Ilschner,
R. Schaller (EPF, Lausanne) (9 lectures).

Programming for the Motorola 68000 microprocessor
H. von Eicken (CERN) (4 lectures).

Parton-parton scattering in hadronic collisions
R. Sosnowski (Warsaw Nuclear Research and CERN) (5 lectures).

Neutrino cosmology
J. Bernstein (Stevens Institute, Hoboken) (4 lectures).

Track recognition and event reconstruction
E. Dahl-Jensen (University of Copenhagen)
M. Della-Negra (LAPP, Annecy, and CERN)
H. Grote, W. Krischer, A. Norton (CERN) (7 lectures).

Numerical methods for data and function approximation
M.G. Cox (National Physical Lab., Teddington) (4 lectures).

Identifying and assessing risks
T.A. Kletz (University of Technology, Loughborough) (5 lectures).

CP violation
A. Zylberstejn (CEN, Saclay), and
J.R. Ellis (CERN) (3 lectures)

Réglagles échantillonnés. Traitement dans l'espace d'état
H. Buhler (EPF, Lausanne) (8 lectures)

Beam-beam interactions
J.F. Schonfeld (Fermilab) (5 lectures)

Medium-range weather forecasting
A. Simmons (ECMRWF, Reading) (5 lectures)

Fusion reactors
R.S. Pease (Culham Laboratory) (5 lectures)

Relativistic nuclear collisions
H. Gutbrod (GSI, Darmstadt) (3 lectures)

Searching for the quark-gluon plasma at CERN and elsewhere
M. Gyulassy (LBL, Berkeley) (3 lectures)

(Audience: maximum 200 - minimum 7.)

TECHNICAL TRAINING

Courses

Mathematics - Physics

Introduction à la physique des particules
J.P. Lagnaux (92 h).

Champs magnétiques et aimants
F. Rohner (40 h).

Atelier de statistiques appliquées
C. Leluc, W. Leo (40 h).

Computer Science

Initiation à l'informatique et aux techniques de programmation
T. D'Amico, H. Slettenhaar (3 sessions of 40 h, 1 session of 80 h).

Introduction to computing and programming techniques
H. Slettenhaar (2 sessions of 40 h, 1 session of 80 h).

Introduction au matériel informatique
H. Slettenhaar (1 session of 40 h).

Programmation en ligne et temps réel
J.A. Bogaerts, A. Lacourt (136 h).

Méthodologie de la programmation
L. Zaffalon (40 h).

Programmation en Pascal
M. Cousin (2 sessions of 36 h).

SCRIPT
J. Gamble (40 h).

WYLBUR avancé
B. Pollermann (48 h)

Microprocesseurs 16 bits: fonctionnement et utilisation
G. Litzistorf, C. Guillaume (2 sessions of 88 h + 5 h of introduction to WYLBUR)

Electronics

Laboratoires d'électronique
S. Cairanti, R. Platteaux, J.P. Bertuzzi, P. Cennini (2 sessions of 88 h).

Systèmes non-linéaires et échantillonnés
G. Baribaud, Ch. Bertuzzi (84 h).

Microprocesseurs 8 bits: applications
J. Feyt, G. Mugnai (2 sessions of 40 h).

Mechanics and courses for mechanicians

Soudure: Initiation
Lycée de Bellegarde (70 h).

Soudure: Perfectionnement
Lycée de Bellegarde (70 h).

Soudabilité et procédés de soudure
J.J. Chêne (40 h + préparation for E.I.G. 28 h).

* The titles of the courses and lectures are given in the language used.

Administration

Techniques d'organisation et de statistiques
A. Brissonnaud, A. Lecomte, G. Lindecker (99 h).

Informatique administrative: WYLBUR
N. Blackburne (2 sessions of 24 h).

328 people attended the technical courses.

Seminars

Electronique de puissance.
H. Foch, M. Metz (2 sessions of 30 h)

Chapitres choisis de mathématiques:
Transformées de Laplace et séries de Fourier
L. Rinolfi, M. Martini (20 h)

Notions de dérivées et d'intégrales
J.P. Dufey, B. Frammery (20 h)

Les réseaux locaux
G. Le Lann, P. Rolin (12 h)

Les fibres optiques
G. Chartier, P. Facq (12 h)

Introduction à la commande numérique des machines-outils
M. Magnin, J. Gagnaire, D. Laffret (30 h)

Le CERN et les contrats d'entreprises
divers intervenants du CERN ($\sim$ 16 h)

151 people attended the technical seminars.

PERSONAL SKILLS AND MANAGEMENT TRAINING

Techniques d'encadrement — par Pierre Artigues,
6 seminars of 5 days, 70 participants.

Rhétorique et présentation efficaces — par Glauco Curetti,
1 seminar of 3 days, 9 participants.

Running, and contributing to, meetings — by Stephen Allender,
1 seminar of 3 days, 9 participants.

Secretarial development — by Niven Charvet,
1 seminar of 3 days, 12 participants.

Supervisor training — by David Gration,
4 seminars of 5 days, 40 participants.

Cours pour secrétaires — par Shelle Rose,
3 seminars of 3 days, 31 participants.

Méthodes et pratiques de la négotiation — par Phillipe Pigallet,
1 seminar of 4 days, 9 participants.

Vie, structure et performance d'un groupe — par Pierre Artigues,
1 seminar of 4 days, 10 participants.

Les relations interpersonnelles dans le cadre du travail — par Pierre Artigues,
1 seminar of 4 days, 10 participants.

Most seminars are preceded by individual interviews or information meetings and are followed 4 to 6 months later by one-day 'follow-up' sessions. These are not counted in the statistics above.

CERN SUMMER STUDENT LECTURE PROGRAMME

Introduction

CERN at the frontier of particle physics
P. Darriulat (1 lecture).

Introduction to particle physics
J.D. Jackson (2 lectures).

Courses

Electronic detectors, instrumentation, and data acquisition
C. Fabjan (3 lectures), W. Bell (1 lecture), D. Burckhart (2 lectures),
A. Bogaerts (1 lecture), and all together (1 demonstration).

Particles and symmetries
V.F. Weisskopf (8 lectures).

Hadronic interactions
L. Camilleri (4 lectures), T. del Prete (1 lecture).

An introduction to accelerators — past, present and future
E. Wilson (4 lectures).

Highlights in e^+e^- physics
W.D. Schlatter (4 lectures).

Seminars

Monte Carlo
F. James (2 lectures).

Underground experiments in Europe — status and perspectives
E. Iarocci (1 lecture).

Missing transverse momentum — a signature for new physics
P. Jenni (1 lecture).

History of the $W^\pm$ and Z^0 search
C. Rubbia (1 lecture).

Experiments on discrete symmetries (PCT)
V.L. Telegdi (2 lectures).

Physics with low-energy antiprotons at LEAR
L. Tauscher (2 lectures).

The ISOLDE programme — studies of exotic nuclei
B. Jonson (2 lectures).

Melting the vacuum with nuclear collisions
W. Willis (1 lecture).

Experimental searches for neutrino oscillations
J. Wotschack (1 lecture).

High-energy physics — where is it going?
H. Schopper (1 lecture).

Wide-area networking for physics
F. Flückiger (1 lecture).

Production of heavy flavours
D. Treille (1 lecture).

Time as a dynamical variable
T.D. Lee (1 lecture).

Other

Physics and Society
V.F. Weisskopf (1 discussion session).

Students Session
A. Drees, S. Haywood, L. Hervas (3 presentations).

(Average attendance: 125; maximum: 207; minimum: 65.)

APPRENTICESHIPS

Number of apprentices from September 1983 to August 1984: 23

Profession	*1st year*	*2nd year*	*3rd year*	*4th year*	*Total*
Laborant en Physique	3	3	3	–	9
Mécanicien-Électronicien	4	4	3	3	14

The three apprentices "Mécaniciens-Electroniciens" who completed their apprenticeship in 1984 obtained the "Certificat fédéral de Capacité".

GENERAL EDUCATION

1. Talks

– **"Science pour tous"**, by R. Carreras:
A series of 26 talks in French intended primarily for people with no scientific training.

(Between 100 and 200 persons attended each talk)

2. Publications

– **"Picked up for you this week"** (R. Carreras):

A weekly sheet in English of press cuttings of general scientific interest.
About 1000 copies per weekly edition and about 3000 copies of the comprehensive edition for the year.

LANGUAGE COURSES

	English			*French*			*German*		
Description of classes	*Number of classes*	*Number of hours*	*Number of students*	*Number of classes*	*Number of hours*	*Number of students*	*Number of classes*	*Number of hours*	*Number of students*
Extensive course (1–6 hours per week)	11	814	82	24	1186	256	–	–	–
Special extensive course (Follow-up, phonetics, drafting, etc.) (2–6 hours per week)	6	390	45	–	–	–	7	245	7
Semi-intensive course (7–12 hours per week)	8	660	69	8	586	53	–	–	–
Total	25	1864	203	32	1772	309	7	245	7

Total number of inscriptions English + French + German 519

Appendix D Scientific Conferences and Schools

The 1984 CERN School of Physics was organized by the Scientific Conference Secretariat in collaboration with the Elementary Particle Physics Group of the University of Bergen. It was held at Lofthus, on the Hardanger Fjord in Norway, from 11 to 24 June 1984, and was attended by 5 students from 3 laboratories in the host country, 61 students from 36 laboratories in 10 Member States, 6 students from CERN, and 5 students from 4 different institutes in non-Member States of CERN.

The lecture programme was as follows:
- J.D. Dowell (Birmingham University): *Proton–antiproton physics*
- D. Haidt (DESY, Hamburg): *Experimental tests of gauge theories*
- J. Iliopoulos (Ecole Normale Supérieure, Paris): *Unification and supersymmetry*
- M. Jacob (CERN): *The top quark*
- C. Jarlskog (Bergen and Stockholm Universities): *Introduction to gauge theories*
- E. Lillestøl (Bergen University and CERN): *Physics in Norway*
- H.B. Nielsen (Niels Bohr Institute and Nordita, Copenhagen): *Random dynamics*
- R. Petronzio (CERN): *QCD*
- F. Ravndal (Oslo University): *Supersymmetry and quantum mechanics*
- S. Rudaz (Minnesota University): *Signals for supersymmetry?*
- B.H. Wiik (DESY, Hamburg): *HERA — the physics and the accelerator*

The 1984 CERN School of Computing was organized by the Scientific Conference Secretariat in collaboration with the Instituto Estudios Energeticos (Junta de Energia Nuclear, Madrid) and the Facultad de Informatica, Barcelona. It was held at Aiguablava on the Costa Brava, Spain, from 9 to 22 September 1984, and was attended by 25 students from 7 laboratories in the host country, 40 students from 34 laboratories in 8 Member States, 17 students from CERN, and 4 students from 4 different institutes in non-Member States of CERN.

The lecture programme was as follows:
- C. Rubbia (CERN): *Opening lecture*
- V. Blobel (Hamburg University): *Unfolding methods in high-energy physics*
- T. Bloch (Ecole Polytechnique, Paris): *The need for massive computing power in different fields of science*
- M.D. Canon (IBM Research Laboratory, San José): *Storage systems and technology: past and future directions*
- F.P. Carrubba (Hewlett Packard Laboratories, Palo Alto): *VLSI: Architecture, design, and packaging*
- R.F. Churchhouse (University College, Cardiff): *Algorithms for parallel computers*
- C. Delobel (IMAG, Grenoble): *Relational data bases*
- R.W. Dobinson (Univ. of Illinois at Champaign-Urbana, and CERN): *Microprocessors: from chips to systems*
- B. Hyams (CERN): *Applications of VLSI in data acquisition and processing*
- K. Miura (Fujitsu Ltd., Kawasaki): *Supercomputing and national projects in Japan*
- B. Randell (The University of Newcastle upon Tyne): *The Newcastle connection* and *An early Spanish computer pioneer*
- R. Rosner (University of London Computer Centre): *Data networks and open systems*
- J. Salicio (JEN, Madrid, and DESY, Hamburg): *Monte Carlo techniques*
- S. Santiago (CERN): *Databases at CERN*
- M.F. Verdejo (Universidad del Pais Vasco): *Expert systems: An overview*
- M. Verges (Universidad Politecnica de Barcelona): *Logic programming: Prolog*
- W. von Rüden (CERN): *Data acquisition for LEP experiments*
- D. Wiegandt (CERN): *Portable computers — portable operating systems*
- I. Willers (CERN): *Single user systems*

The Scientific Conference Secretariat also made the material arrangements for the Conference on 'Teaching Modern Physics' held at CERN from 24 to 28 September 1984 (75 participants).

Appendix E

List of VIP visites in 1984

JANUARY

12 Mr S. GUSTAFSSON, Président, Swedish Natural Sciences Research Council

25 H.E. Ambassador R. PAOLINI, Permanent Representative of Italy to the United Nations Office and the other International Organizations at Geneva

FEBRUARY

10 Group of Ambassadors to the United Nations Conference on Disarmament

MARCH

15 Dr R. KRUMSIEK, Minister for Science and Research of the Land of North-Rhine-Westphalia, Federal Republic of Germany

19 Dr A. PROBST, Secretary of State at the Federal Ministry for Research and Technology, Federal Republic of Germany

31 Mr H. FISCHER, Federal Minister for Sciences, Austria

APRIL

19 United Kingdom Department of Trade and Industry:
Mr S. BURBRIDGE, Under-Secretary of State
Mr D. WISEMAN, Head of Research and Technology
Mr P. ROBINSON, Export Europe Branch

MAY

09 Professors and senior administrators from universities in Sweden

09 Swiss National Fund for Scientific Research

JUNE

01 Bank officials from China

22 Dr G.W. CHANTRY, Science Attaché, British Embassy, Bonn, Federal Republic of Germany

25 Professor S. ERLANDER, Vice-Chancellor, Linköping University and Institute of Technology, Linköping, Sweden
Professor J.-O. PALMBERG, Dean, Linköping University and Institute of Technology, Linköping, Sweden

JULY

02 Delegation from the Royal Institution, London (19 members)

AUGUST

13 Mr ter HORST, Netherlands

20 H.E. Ambassador R. van SCHAIK, Permanent Representative of the Netherlands to the United Nations Office and the other International Organizations at Geneva
Mr H. HEINEMANN, Deputy Permanent Representative of the Netherlands
Mr J. JURGENS, Consul honorary of the Netherlands, Geneva

20-21 Mr R. CHABBAL, Chairman, Research Group to the Ministry for Research and Technology, France

SEPTEMBER

21 30th Anniversary of the Entry into Force of the Convention for the Establishment of CERN, in the presence of:
His Majesty KING JUAN CARLOS I of Spain
Her Majesty QUEEN SOFIA
The Princesses ELENA and CRISTINA
The Marquis of MONDEJAR, Head of the Royal Household
General FERNANDEZ CAMPOS, Secretary-General to the Royal Household

Mr H. CURIEN, Minister for Industry and Research, France
Mr L. GRANELLI, Minister for Scientific Research, Italy
Mr L.R. LANGSLET, Minister for Cultural and Scientific Affairs, Norway
Mr C. SOLCHAGA, Minister for Industry and Energy, Spain
Mr M.P. BROOKE, Secretary of State for Education and Science, United Kingdom
Mrs C. VIRGILI, Secretary of State for Research and the Universities, Spain

Professor E. AMALDI, former Secretary-General, European Council for Nuclear Research
Professor P. AUGER, former Director, Division of Exact and Natural Sciences, UNESCO
Mr J.H. BANNIER, former President, CERN Council
Mr D. de ROUGEMONT, writer, Chairman, European Cultural Centre
Professor I. RABI, Nobel Prize for Physics, 1944
Professor V.F. WEISSKOPF, former Director-General of CERN

Mr E. SUY, Director-General, European Office of the United Nations, Geneva
Mr S.J. SPAULDING, the Director of the International Bureau of Education
Mr R.E. BUTLER, Secretary-General, of the International Telecommunications Union
Mr D. SMITH, Deputy Secretary-General, World Meteorological Organization

The Member States Permanent Representatives at Geneva and Ambassadors in Bern
The Delegates of the Member States to the CERN Council and their Representatives on various CERN Committees
The Representatives of the French Prefectural, Administrative and Departmental authorities
The Representatives of the Swiss Federal, Cantonal and Communal authorities
The Representatives of the European and international scientific community

28 Parliamentarians from the Netherlands

OCTOBER

02 Mr R. JACKSON, M.P., United Kingdom

10 Professor K.H. BECKURTS and Mr H. FÜLLUNG, Siemens, Federal Republic of Germany

NOVEMBER

01 Mr T. di ROMAGNANO, Consul-General of Italy, Geneva

22–25 Delegation from the Swedish Research Council (Physics) (15 members)

26 H.E. Mr F. MUHEIM, Directorate for International Organizations, Federal Department of Foreign Affairs, Bern, Switzerland

28 General A. de TORRES SPINOSA, Spain

DECEMBER

10 Professor H. DETTER and Professor P. KOSS, Directors, Austrian Research Centre, Seibersdorf, Austria

12 Mr P. CHAMPENOIS, Consul-General of Belgium, Geneva

15–18 Institute for High-Energy Physics, Berlin-Zeuthen, German Democratic Republic:
Professor C. GROTE, Secretary-General
Dr. K. LANIUS, Director
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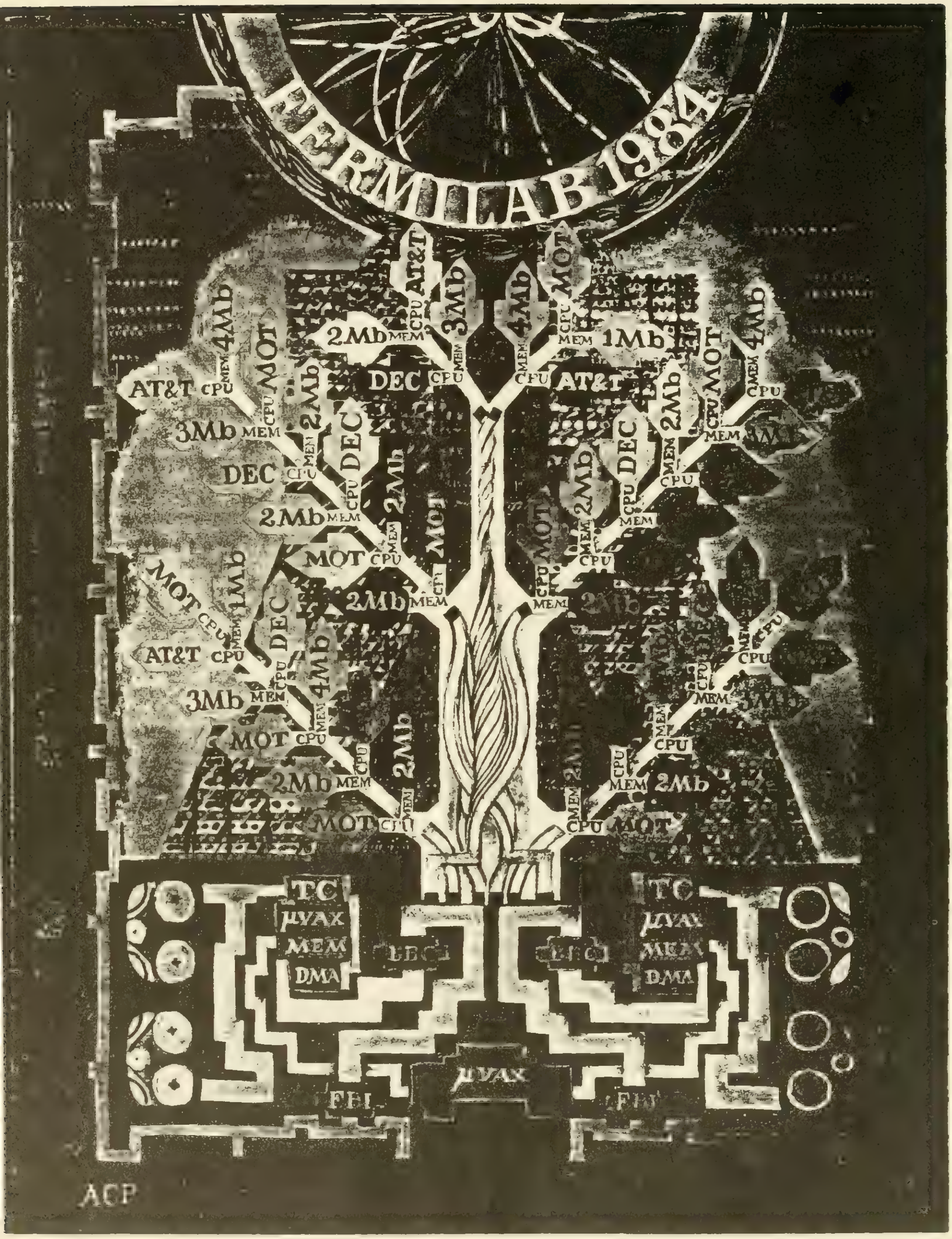
THE PRINTING OF THE THIRTIETH ANNUAL REPORT OF THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH, WAS COMPLETED ON THE TWENTY-FIRST DAY OF JUNE NINETEEN HUNDRED AND EIGHTY-FIVE BY THE DOCUMENTATION DEPARTMENT AT CERN, GENEVA, SWITZERLAND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Fermilab 1984

The cover: Adequate computing resources have become a critically scarce tool that high-energy physicists need to carry out their science. Fermilab's Advanced Computer Program (ACP) is attacking the problem with the development of a multimicroprocessor system based on the latest in commercially available integrated circuits (see page 49). The cover is Angela Gonzales' abstraction of the tree structure of the ACP system and is based on the figure on page 54. The branches of the tree support memory (MEM) and numerous central processing units (CPUs). The memory leaves come in various sizes measured in megabytes (Mb). The 32-bit microCPUs are now becoming available from a number of firms, including AT&T, Motorola (MOT), and Digital Equipment Corporation (DEC). The branches and trunk represent high-speed busses and a switch that carry data from the roots which handle the input of raw information and the final output of results. Four tape drives appear at the corners of the roots. At the center are various controllers and interfaces that manage the system. In online trigger applications, a Fastbus Interface (FBI) connects to data acquisition hardware in Fastbus standard crates. The background suggests the intricacy of the micron dimension patterns seen in photomicrographs of the incredible 32-bit microprocessors used in the leaves. Above the title is a typical colliding-beam experiment event. Behind the tree, lurking in the magenta mist, is Fermilab's Wilson Hall, teeming with researchers anxious to reconstruct such events.

— Tom Nash

Fermilab 1984

Annual Report of the Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory
Batavia, Illinois

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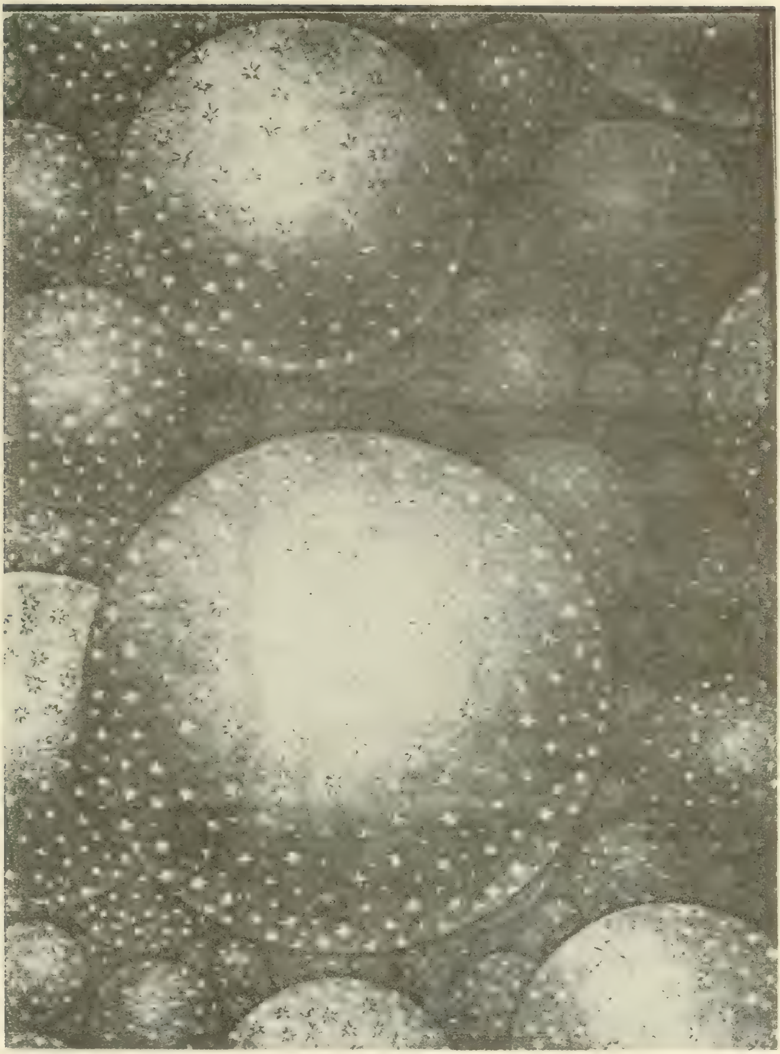

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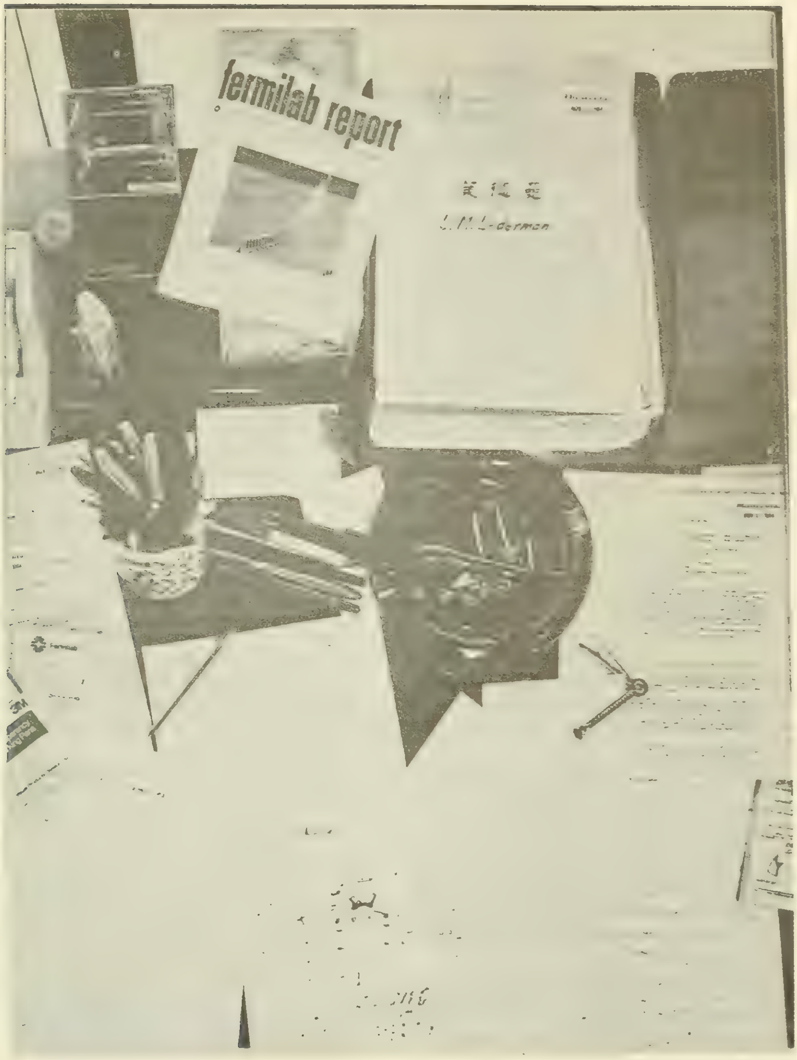
Cosmological Inflation

← Out of the union of ideas in particle physics and cosmology has come the theory of cosmological inflation; a concept that has revolutionized the way we think about the earliest moments of the big bang. As we explore higher energies and probe matter on smaller scales, we become aware of the existence of hidden and beautiful symmetries that are not apparent in the Universe today, but should have been manifest at the enormous temperatures in the first microseconds of the big bang. As the Universe cooled, it underwent a series of phase transitions in which the underlying symmetries were broken step by step. Inflation is the theory that in one of these transitions a single bubble of the low-symmetry phase rapidly expanded to a size large enough to encompass our entire observable Universe.

— E. Kolb



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I. State of the Laboratory

The year 1984 may be summarized by its major activity, the Taming of the Tevatron. (The names Energy Saver and Energy Doubler should pass into history even though the new superconducting accelerator did double and does save energy, some 40 megawatts, in fact). Our runs in '84 were ragged as we tried to manage the complexity of the new machinery, the neglect of the old machines and the implementation of new beam lines and new experiments. However, enough of our goals were met to list the run as successful. A score card is presented elsewhere in this volume. The unfinished part of the Tevatron, the Antiproton Source (Tevatron I) was also a high priority activity and, when we add in the continuing construction of the Collider Detector Facility (CDF), we see a very substantial effort. In the euphoria of doing physics again we were struck with the fact that, since 1979, the Laboratory had been gradually transformed in order to best manage its construction tasks. This put us in poor posture to apply creative attention to the challenges of getting physics out of the Tevatron. So we reorganized. The aim is as stated, to finish our construction tasks as quickly as possible and to organize ourselves to conquer the planet in the years from now until the Tevatron fades into the shadow of the Supercollider. *Sic transit gloria mundi.*

The reorganization strategy was to deploy our strengths to match the altered priorities of an operating laboratory. A simplified circuit diagram is around here somewhere. The Laboratory priorities need to be reiterated; they are logical but the large overlaps still make for confusion and uncertainty. With customary caveats that a numerical ordering on a flat page does injustice to a multidimensional nature of the problem, we list:

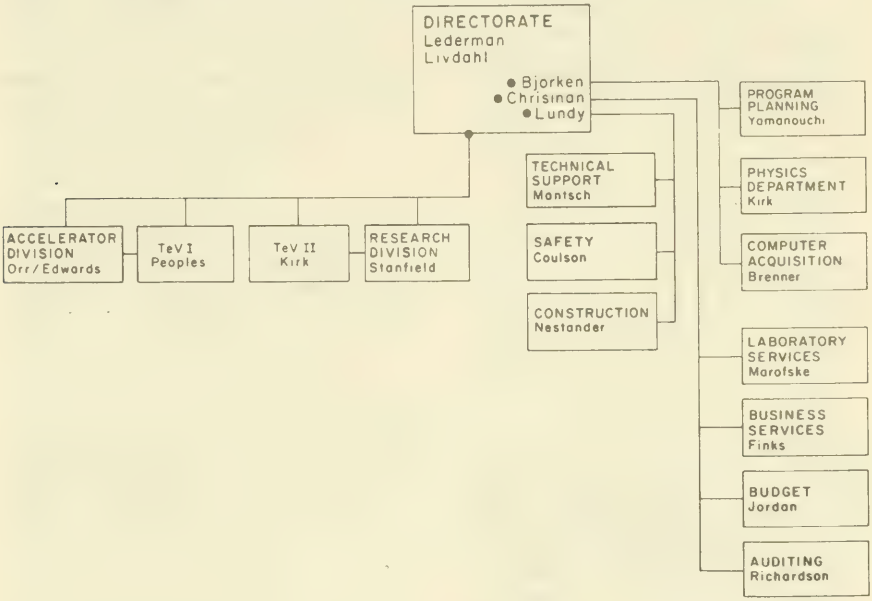
1. We must bring the accelerator up for reliability and increasing intensity to service the 1985 fixed-target program.
2. We must complete TeV I (the $\bar{p}$ source) so that a good physics run can be carried out in the fall of '86.
3. This implies the essential completion of an excellent detector, CDF, capable of addressing the new physics issues that go with 2 TeV.
4. TeV II, the fixed-target beam lines and areas, must be completed (within budget, of course) on time and the 1986 fixed-target experiments and beam lines must be ready to go by spring 1986.
5. The Tevatron accelerator must reach close to 1000 GeV by a combination of replacing weak magnets and lowering the ring temperature about 0.5°K.
6. The second major colliding beam detector at D0 must be brought on line, phased to do some physics by 1988 and completed soon thereafter. We need to convince whoever will listen that this is deserving of a more rapid funding pace than our present projections allow.
7. We must continue to support the development of our computer facilities via manpower and a major new addition to the Computer Center. Even this will not be enough to serve the entire Tevatron program, and we must support the Advanced Computer Project.
8. We must continue to improve the intellectual environment of the Laboratory: here we recognize the important role of the Theoretical Physics group, now aided by our maturing Astrophysics Group.

A comment: We are concerned about the Fermilab "post-docs" since Fermilab's atmospherics are different from universities' and different from SLAC, BNL, and LBL. Here we note that we do not have permanent groups under semi-permanent group leaders. The responsibility for the intellectual care and feeding of post-docs (poor beasts of burden, only exceeded by graduate students) is then diffuse and our Physics Department is now instructed to study and solve the problem. Here we should add that the reorganization must assume that Fermilab physics staff will have greater opportunities to participate in research and, again, the appropriate structure to see to this is the Physics Department.

9. We have serious responsibilities relative to SSC on at least two fronts. One is to do our share of the national effort on R&D and design. The other is to look into the Tevatron as a possible injector. It seems clear that any improvements in the Tevatron as SSC injector will help the current program. A third obligation is to provide assistance to the State of Illinois (and anyone else who asks) in efforts to compete for the SSC.

10.-15. Here we simply shrug and remind our readers that we do R&D on instrumentation, we stimulate the HEP community to think hard about new experiments via workshops, we reach out to the external community for science education, technology transfer, collaboration with developing countries, etc., etc.

The foregoing is a restatement of the goals of the Laboratory over the next several years. The remainder of this overview and the articles that follow constitute a progress report.



Particle Theory

Reviewing those highlights which are not described in greater detail in this issue, we note first that the Theory group has now grown to six permanent members (Bardeen, Bjorken, Eichten, McLerran, Quigg, and Thacker) and there are now six associate scientists (Ellis, Hill, Parke, Pisarski, Schonfeld, and Taylor). There are seven post-docs and the usual deluge of unusual visitors. In addition to their own work on the full spectrum of particle theory fascinations, Theory has served the community via very active participation in SSC activities. A major product is the "bible" of SSC physics (the Reviews of Modern Physics article known as EHLQ, pronounced ELK, probably because the authors are Eichten, Hinchliffe, Lane, and Quigg.)

The Physics of Theory

The phenomenology relevant to colliding beam physics has been a major focus of research. A detailed survey of SSC physics prospects was completed (Eichten, Quigg), along with related work on the signals for Higgs bosons and technicolor. The search for supersymmetry has been brought into sharper focus with a critical examination of the current limits and the detection prospects (Eichten, Quigg). The interpretation of high-energy jet production at the Sp$\bar{p}$S collider has been clarified by Monte Carlo studies (Sjostrand) and by perturbative QCD calculations (Ellis, Parke, Taylor).

Significant progress has also been achieved in the application of lattice gauge theory to physics problems. For the first time, hadronic decay parameters have been computed using lattice Monte Carlo methods (Thacker). A study of finite-size effects on spectrum calculations has also been completed (Thacker). Monte Carlo methods have been applied to the study of the renormalization properties of QCD and to phase structure of the theory at finite temperature (Das). Lattice methods have also been adapted to the study of possible composite structure of weak interactions (Sexton).

Research interests have also turned to higher dimensions, gravity, supergravity, and strings. The structure of anomalies for gauge and gravitational theories in any dimension was clarified (Bardeen). The effects of quantum fluctuations on the vacuum structure of Kaluza-Klein models have been analyzed (Rubin). A covariant functional Schrodinger method has been developed to study the quantum evolution of the states in the early universe and the implications of inflationary scenarios (Hill). The consistency of renormalizable, higher derivative theories of gravity has been examined, including the implications for the vanishing of the cosmological constant (Pisarski).

Mathematical methods have been developed for the study of colliding beam instabilities in electron-positron storage rings (Schonfeld).

In addition to publishing to avoid perishing, the group has maintained the pace of theory seminar, wine and cheese seminar, Journal Club, and a new TeV I Collider Physics Journal Club. Academic lectures were given on a wide set of subjects selected by the trapped population of graduate students and post-docs. In a more ideal world, these honored guests would be living on a university campus where, in that ideal world, one could walk to the accelerator.

NASA/Fermilab Astrophysics Center

The NASA/Fermilab Astrophysics Center was started at Fermilab in 1983 with a grant from the NASA Office of Space Science and Applications Innovative Research Program. In less than two years Fermilab has become recognized worldwide as the center for work at the forefront of the interface of particle physics with astrophysics and cosmology.

Cosmology is the study of the origin and evolution of the Universe. Cosmology includes everything from the origin of the Universe, to the primordial production of light nuclei, to the decoupling of the present microwave background radiation, to galaxy formation, to the present structure of galaxies, clusters of galaxies, and beyond. Cosmology provides a background upon which we understand and interpret the Universe in which we live. In the past few years, it has become increasingly apparent that an understanding of the present large-scale structure of the Universe is impossible without understanding its small-scale structure. The discovery of this deep connection between particle physics and cosmology has started the entire new field of particle physics and cosmology. Fermilab offers a rich and unique environment for research at the particle physics/astrophysics interface.

The Physics of Astrophysics

One of the oldest of the modern cosmological questions has to do with the "missing mass" necessary to "close" the Universe. If there is enough mass in the Universe, the expansion we observe will eventually stop, and the Universe will recollapse. The possibility that the "missing mass" in the Universe is in the form of the decay products of massive neutrinos has been studied by members of the Fermilab Astrophysics group. This possibility was first proposed in 1978 by Dicus (Texas), Kolb (Fermilab), and Teplitz (VPI). In the past year at Fermilab, the idea has been developed, and the

effect of decaying particles in galaxy formation has been studied. Turner (Fermilab/Chicago), Steigman (Bartol), and Krauss (Harvard) extended the original idea in a **Physical Review** letter. Other ideas for decaying particles have been studied by Schramm (Fermilab/Chicago), Gelmini (CERN), and Valle (Rutherford) in an article in **Physics Letters**. Olive (Fermilab), Schramm (Fermilab/Chicago), and Srednicki (Santa Barbara) have considered the possibility that the decay products of gravitinos could close the Universe. Olive (Fermilab), Seckel (Fermilab), and Vishniac (Texas) have studied further astrophysical effects of decaying particles in an article in **Astrophysical Journal**. Finally, Kolb (Fermilab) reviewed the staus of the cosmological effects of decaying particles at NEUTRINO '84, the yearly international neutrino conference.

"Inner Space/Outer Space"

During the first week of May, an international conference on science at the interface of particle physics and cosmology/astrophysics was held at Fermilab. The conference was organized by members of the Fermilab Astrophysics Center. The "Inner Space/Outer Space" conference was attended by 230 scientists, including astronomers, astrophysicists, cosmologists, low-temperature physicists, and particle theorists and experimentalists. Plans are now being made to hold annual workshops on cosmology and particle physics at Fermilab. The proceedings of the May 1984 conference will soon be published by the University of Chicago Press. Inner Space/Outer Space conference T-shirts have become collectors items.

Astrophysics Seminar Series

In addition to the annual conference, the Astrophysics Center holds a weekly seminar series on Monday afternoons. In the spring of 1984 the seminar series focused on the cosmological implication of theories of extra dimensions. The fall seminar series topic was the microwave background radiation, and its implications for galaxy formation. The Monday astrophysics seminars often complement the Tuesday theoretical physics seminars. Several of the Laboratory colloquia have been in various areas of astrophysics. Cosmology and astrophysics have also become part of the public image of the Laboratory. Michael Turner of the Astrophysics Group gave a public lecture at Fermilab on the cosmology-particle physics connection. This Friday night public lecture was sponsored by the Fermilab Auditorium Committee and was attended by over 700 members of the local community. One of the goals of the Astrophysics Group is to make cosmology and astrophysics an integral part of the intellectual atmosphere of Fermilab. By doing so, particle physicists at Fermilab are provided a unique perspective through which they may interpret and appreciate advances in their field in a wider scope of its influence in other fields of physics.

Astrophysics Group

The present Astrophysics Group was originally headed by Edward Kolb, who joined Fermilab from the Theoretical Astrophysics group at Los Alamos National Laboratory, and by Michael Turner, who spent the '83-'84 academic year at Fermilab on leave from the University of Chicago. In the fall of 1984, Turner returned to the University of Chicago, but will continue to spend one quarter per year in residence at Fermilab as a visiting scientist.

In the fall, Alex Szalay joined the Group. Alex is a Hungarian astrophysicist who specializes in models of galaxy formation. Szalay will be a visiting staff member and will be at Fermilab for eighteen months. David Schramm, from the University of Chicago, will continue to split his time between Fermilab and Chicago. This fall, Bernard Carr of the University of Cambridge was in residence. The active visitor program benefits both Fermilab and the astrophysics community by making experimental and theoretical advances in particle physics accessible to the astrophysics community. In addition to Kolb, Turner, Szalay, Schramm, and visitors, the Group has four post-docs and several graduate students, making it one of the largest cosmology groups in the civilized world, perhaps in the universe, certainly in Warrenville, Illinois.

Tevatron I, The Antiproton Source and Collider

This is the project which will permit Fermilab to produce collisions between counter-rotating beams of protons and antiprotons. When we bring the beams close to 1 TeV, the resulting 2 TeV will be a planetary record energy — over three times the energy of the CERN collider.

TeV I proposes to extract protons from the old Main Ring and target them to produce antiprotons. These are collected, stored, cooled, and accumulated in two new concentric rings located just south of the Booster. No, the particle choreography is not complete: the above processes are sandwiched by rf manipulations before extraction and by reinjection of ice-cold antiprotons in the Main Ring for acceleration and delivery to the Tevatron.

The manager of TeV I goes on to write:

If physics were a horse race, the Tevatron I project would be spinning out of the final turn at the top of the stretch. 1984 has been a year of major accomplishments for TeV I in both conventional construction and technical components. The story can perhaps be best told in the photo essay in this Report.

The accomplishments of the project are made even more noteworthy by the obstacles that had to be overcome this year. The year began with a terrible winter for construction. In spite of the weather, construction of the tun-

nels and service buildings was completed, and we have been installing equipment for several months. More and more of the Tevatron I Section has moved out to the trailers next to the rings to be close to their work. The Target Station and Target Service Building are also complete. During the summer shutdown, the Main-Ring tunnel was uncovered and new, wider tunnel sections installed for Tev I extraction.

The technical components have also moved ahead, although that work has also had obstacles. The TeV I Debuncher, Accumulator, and transport magnets are larger and have tighter field-quality specifications than any conventional magnets Fermilab has built before. The year saw all the quadrupoles of both aperture sizes completed, measured, and accepted. The coils for nearly all of the dipoles are finished. The assembly of the laminations into magnet cores did not come easily. The magnet performance has been affected by the quality of the steel and the condition of the stamping die. By carefully testing the magnetic properties of several hundred samples of steel and accurately measuring the lamination dimensions, it has been possible to obtain the desired quality. In some instances magnets which did not meet the demanding tolerances of the project were brought to specifications by adding a small number of thin shims. At the end of the year, installation of magnets in the tunnel was underway.

There were also some difficulties to overcome in the target area. The first lithium lens for antiproton collection failed when the bolts holding the assembly together yielded. When the cause of this failure was remedied on prototypes two and three, cracks developed in the titanium water jacket. Detailed investigation showed that this failure was caused by metal fatigue and a redesign has fixed the problem. The most advanced prototype lithium lens has now been pulsed to its design current more than 100,000 times. Lens number 2 has operated for more than one million pulses, albeit at 50% of the design current, in the AA target station at CERN. Other special magnets and devices for the Target Station are being fabricated.

Equipment for stochastic cooling is also being assembled. After some initial problems, the traveling-wave tube amplifiers for cooling met design specifications. The pickups and kickers, preamplifiers, and other electronics are under construction and the superconducting correlator filter is well along. Similarly, all of the enormous amounts of equipment for the two major storage rings are well along in fabrication, including the controls system.

During 1984, the superconducting low-beta system that will squeeze the beam down and improve the luminosity at B0 in the Tevatron was installed and successfully tested at 800 GeV. At the end of the year, the Main-Ring Overpass to carry the beam around the detector at D0 was installed and successfully operated. The Main Ring bunch-coalescing cavities, used to increase the peak proton intensity on the antiproton production target, were installed in 1984 and are ready to go.

At the end of 1984, the people of the Tevatron I Section were all busy installing, surveying, and testing equipment. The new year, 1985, should see us thunder down the home stretch and cross the finish line.

Tevatron II, The Fixed-Target Program

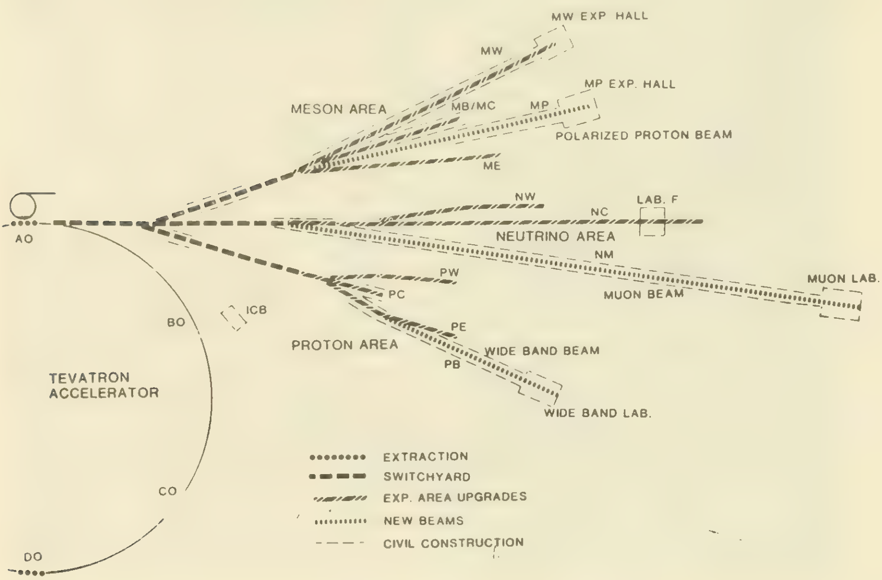
1984 was the third year of the TeV II construction project and will probably turn out to be the year in which the activity on this project reached an almost unbearable crescendo. The construction project as a whole is divided roughly into two parts, a technical upgrade of the primary beam transport facilities from 400 to 1000 GeV, and a civil construction portion in which various experimental halls, beam enclosures, and other facilities are constructed to accommodate both the primary beam upgrade and the experimental facilities that will be needed for the 1000-GeV fixed-target program.

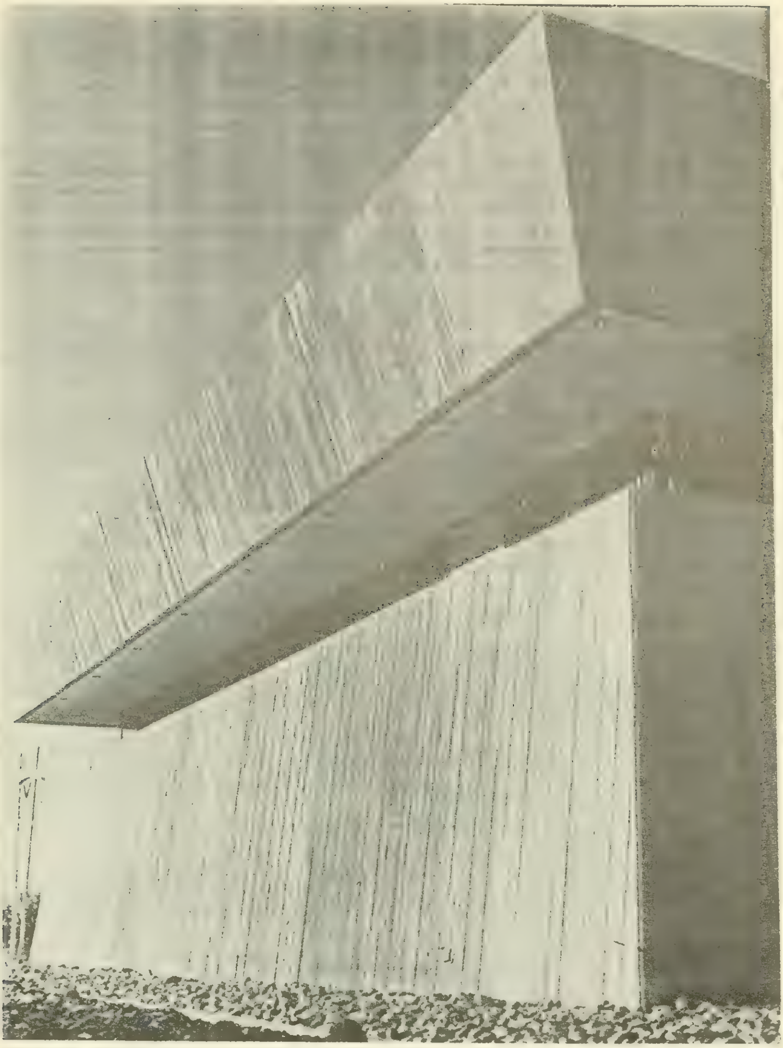
During the past year, the primary emphasis for the technical upgrade part of the TeV II Project has been in developing and installing primary beam transports for new beams that had not existed prior to Tevatron II. These were specifically the Wide Band Beam in the Proton Area and the new Muon Beam in the Neutrino Area. The extraction of fast beam for the conventional neutrino program was also an area of significant activity in 1984. Finally, a significant amount of work took place in construction of the M-West Target Pile. This new primary target station will become the source of a high-energy hadron beam to be built in 1985 and 1986.

A majority of the activity in the TeV II project in 1984 was concentrated in civil construction projects associated with the new Wide Band Photon Beam and the new Muon Beam. For the former, two existing enclosures in the Proton Area were converted into fully shielded areas capable of transporting and targeting primary proton beams. One of these, the PE4 enclosure, will be the source of the Wide Band Beam. It was necessary to partly demolish the old enclosure and rebuild it in order to insure the desired amount of radiation shielding and achieve the technical capabilities needed for the Wide Band Beam.

Downstream of this enclosure, a new tunnel

TeV II Construction Areas





extension was added which will be used for the early sections of the Wide Band Beam transport; a second new enclosure was built next to the Tagged Photon Laboratory for momentum selection, and downstream of the momentum selection enclosure the new Wide Band Experimental Hall and counting house were constructed. This last is far and away the largest TeV II project in the Proton Area and the hall has been under construction since early 1984. The new building will house two experiments, E-687 and E-683, both of which have been approved to do photon experiments in the 1986 run.

Through experience, it has become clear that the construction of a new experimental hall takes almost one year from the time that the bid package is released until the building is fully available to experimenters. Work on the Wide Band Hall began in the early spring of 1984; it is hoped that the building will be available for full use by the experimenters by February of 1985. In order to help the users get an early start in the erection of their apparatus, early occupancy of the high bay areas of the hall has been arranged. This is a strategy that seems to pay significant time dividends and is much appreciated by experimenters.

Meanwhile, back at the Neutrino Area, an even larger civil construction effort has been underway in 1984. This is the construction of the new Muon Laboratory, and of the twenty-four beam line enclosures that are necessary for the new muon beam. These two projects have been pursued as separate construction contracts and, as noted in the Wide Band case, the laboratory building will probably take about one year to complete. The new Muon Lab was started in February of 1984 and is expected to be fully complete only in February 1985. The Muon Laboratory is a large building that combines a high bay experimental area and the associated counting and computing rooms in a single structure. This building, when complete, will be one of the most striking and aesthetically pleasing structures on the Fermilab site. An itinerant architectural consultant, one R. R. Wilson, is to be credited here.

If all the muon beam civil construction can be completed on schedule, it is hoped that the Muon Beam will be commissioned in the spring of 1985. Perhaps it will even be possible to begin preliminary tests for E-665, the experiment that plans to take data in this beam in 1986.

In addition to the active civil construction projects, a great deal of planning in the Tevatron Construction Group has gone forward in 1984 for the final phase of the Tevatron II Project, the new beams for the Meson Area. The two beams presently planned for this area are the M West Pion Beam (which will be the only pion beam in the Laboratory capable of going to 800

GeV) and the Polarized Proton Beam, a facility unique in the world. This latter beam will exploit the observed experimental fact that polarization persists in secondary particles even at high energies. This polarization, an early Fermilab discovery, was theoretically unexpected.

In 1984, the conceptual plan for the Meson Area civil construction was completed and the engineering design begun. In order to speed up construction of the M-West Experimental Hall, a plan was decided upon to phase the construction. It is now hoped that the foundation for this building, its associated counting house, and a related service building will be completed before severe winter weather sets in. Then, even during the coldest months, it is anticipated that structural steel can be erected by taking advantage of favorable breaks in the weather. This will enable us to get a rapid start on the rest of the buildings in the spring of 1985 and, hopefully, complete the M-West Experimental Hall by the end of summer.

Unfortunately, the Polarized Proton Hall cannot be maintained on the same rapid schedule, and this Hall will probably not be complete until the end of 1985. The associated beam line enclosures for the M West Pion Beam and the Polarized Proton Beam are also under design as 1984 draws to a close, and precast concrete sections needed in their construction will be procured during the winter. Next spring, the civil construction on these beam line enclosures will be undertaken at approximately the same time as the structures for the experimental halls begin to take shape.

The Physics of TeV II

The reorganization created an Associate Director for Physics and Dr. J. D. Bjorken was named to this post. His article addressing TeV II physics is in this volume.

In 1984, we began to "review" the future of the fixed-target program. This began with a fine workshop on Fixed-Target Physics. Out of this came an organization of users devoted to this subject: Tevatron Association of Fixed-Target Spokespersons (TAFTS). This was followed by in-depth workshops on Vertex Detection (September), Direct Neutral Lepton Workshop (October), and Hyperon Physics at the Tevatron (December). The richness and potential of Tevatron research was made crystal clear in these studies. Much of this clarity is contained in Bjorken's section of this review. The Santa Fe meeting of the Division of Particles and Fields witnessed an explosion of contributions coming out of the Tevatron. We counted about 50 papers. The most dramatic result was the clarification of a long-standing puzzle: the beta decay of the sigma hyperon. Some four previous experiments, collecting a grand total of about 400 examples of this decay, produced a unanimous result that was in disagreement with standard theory. A Fermilab-Yale-Iowa State-Leningrad-Elmhurst collaboration, capitalizing on the power of the Tevatron, collected some 80,000 sigma beta decay events and a new result which settled the issue in favor of the theory.

This is the opening curtain in the long vision we have had of providing facilities for high-energy physics which would be seminal to the evolution of the field. The Tevatron provides the combination of the essential data of fixed-target research and the bold thrust into the highest energy domain. If the beautiful results of this experiment on sigma-beta decay are indicative of the coming scientific payoff of the Tevatron II Project, we can look forward to a long, satisfying, and significant impact on the high-energy physics community.

The Rest of the Laboratory

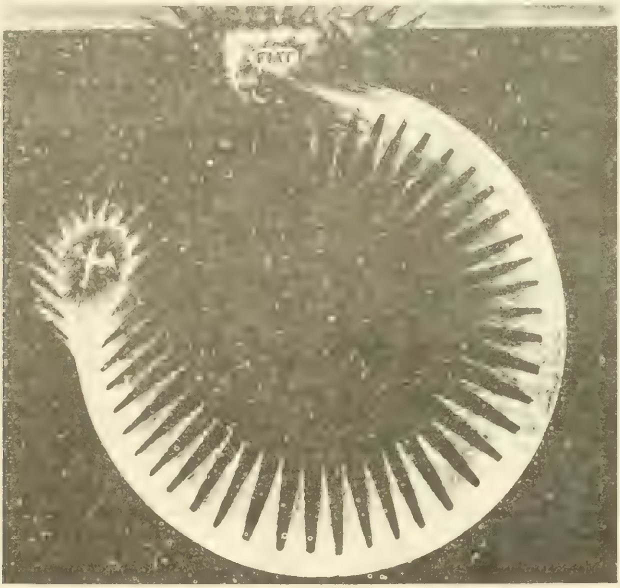
Other articles in this volume address the Saver, the fixed-target physics program, some magnet production nostalgia, the Advanced Computer Project, and photo essays on TeV I and the Collider Detector at Fermilab. We should mention that 1984 saw the final DOE approval of the D0 collider detector — now a mature design with emphasis on complementary attributes to CDF. In combination, the two detectors will make a powerful attack on the *terra incognita* of 2-TeV collisions. The trouble is the pace with which funding will become available for D0. In 1985 we will try hard to convince everyone who will listen that D0 must go faster and be complete as soon as possible. We must not lose the thrust of 2-TeV physics.

In this issue, what of the unsung heroes in the

support sectors of the Laboratory — of those that pay the payroll and buy the things and write the contracts and serve the food and maintain the Lab and plow the roads and groom the buffaloes and fill the auditorium and machine the parts and produce the drawings and invent the gadgets and guard the ramparts...of all of thee we sing!

Philosophical Finale I

At a History of Science Society meeting in November we were stimulated to review the sociology of high-energy physics. Sources indicate that in the 1950s one could do two or so experiments a year, each one involving two or four collaborators. In a more-or-less gradual development, one now does an experiment every three years with 20 or 40 collaborators in the fixed-target program and one enjoys 100-200 dear colleagues in the collider teams. The colliders take three to six years to build but of course physics pours out. It may be difficult to explain this to your humanities colleague or your father-in-law, but the large group isn't necessarily a catastrophe. Participants combine to build a complex detector, each university subteam of five or fifteen fully challenged to deliver a complex component. When physics comes, the subteams that have developed particular pieces have use of all the components of a coherent detector. We have not yet learned to apportion special credit to these subteams in recognition of how the various pieces of physics are really done, but this will come. When we face SSC detectors with, perhaps 300-500 member teams, the mind boggles, the hands sweat, the pulse quickens. We must be very creative in treating the sociology here. CDF and D0 will be U.S. pilot programs. The central issue is whether the universities, the intellectual owners of this Laboratory, can continue to use and manage this research with profit and pleasure.



Philosophical Finale II

Avid readers of the science fiction of the '30s may be impatient with the failure of the '80s to match the predicted technology, lifestyle, and romanticism, but we can hardly fault the progress of physics. At Fermilab, overworked, obsessed with getting through the day and week not to mention the fiscal year, we tend to neglect the culture of physics, the progress made by our former colleagues, fellow graduate students in such dynamic fields as quantum optics, condensed matter, and polymer physics. We tend to overlook the interdependence of our discipline, yet some of our theorists first learned about symmetry-breaking from condensed matter theory, and our superconducting alloys were developed in materials science labs. We should be pleased that the first priorities among colleagues in nuclear science and in materials science is for powerful accelerators to provide electrons for nuclear probes and for blinding synchrotron light. We are witnessing changes in the boundaries of our subject as relativistic heavy ion collisions merge from one side, and on the other side we have a de facto joining of particle physics and cosmology.

Why this sudden glow of physics culture? Quite frankly, it comes from the vision of the high-energy community (some critics would call it an apparition) which is the superaccelerator, SSC. When this is discussed outside, with good scientists in other disciplines, there results a lively exchange which often leads to a new appreciation of the interdependence of our diverse fascinations.

The decision makers will be facing proposals for a variety of expensive, centrally shared facilities in the next five years, and some very deep thinking will have to go into setting priorities. This is because it is highly unlikely that there is enough statesmanship around to recognize that a doubling of the very basic research budget (say from $3 billion to $6 billion) would very likely produce fantastic social and economic dividends over the next three decades. We hasten to add that basic research, and our own subject, have fared relatively well in recent years. We do have a Tevatron and we will use it as well as we can! We will do this in spite of the admonition not of the DOE, not of our graduate students but of that seventeenth century poet and anguished spirit, John Donne:

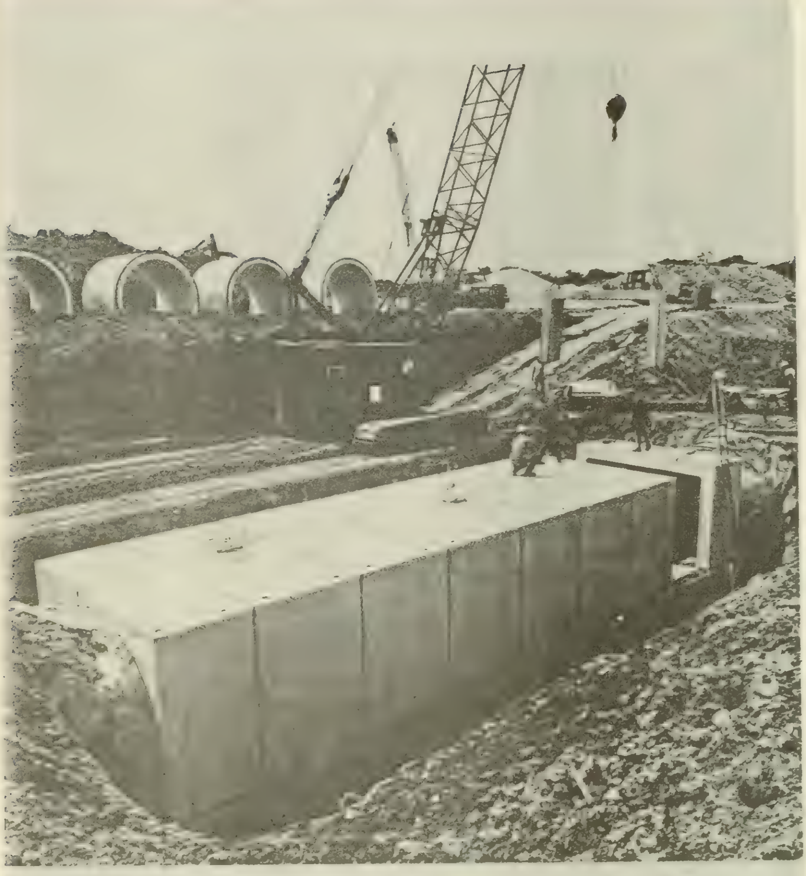
We gape, we grasp, we gripe, add store to store;
Enough requires too much; too much craves more. . .
Thus we, poor little worlds! with blood and sweat,
In vain attempts to comprehend the great.

Leon M. Lederman

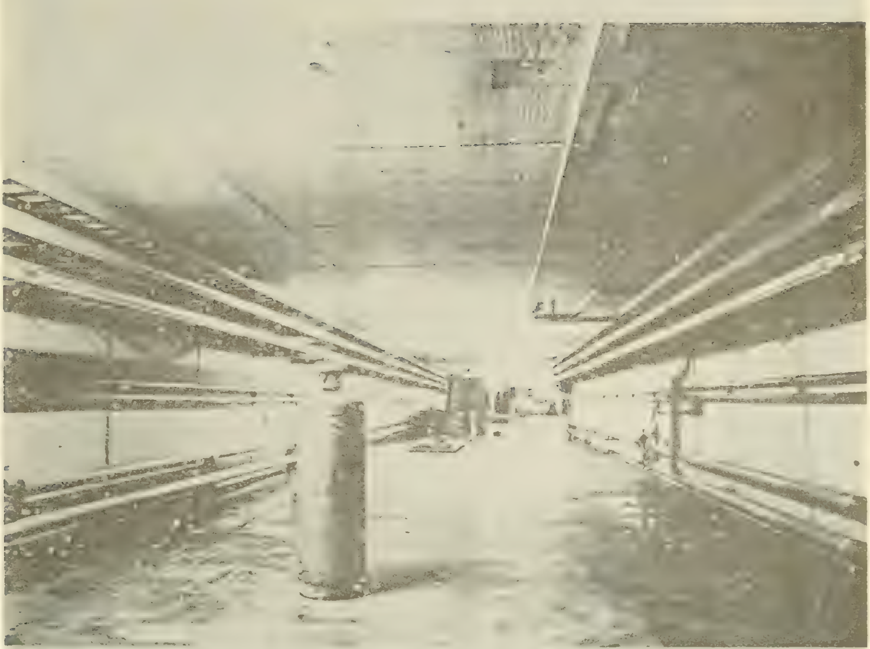
II. Construction of the TeV I Antiproton Source

The Antiproton Source from the air, looking north toward Wilson Hall. The Target Service Building is at the lower right next to the Main Ring. The three service buildings clearly show the triangular shape of the Antiproton Source rings.

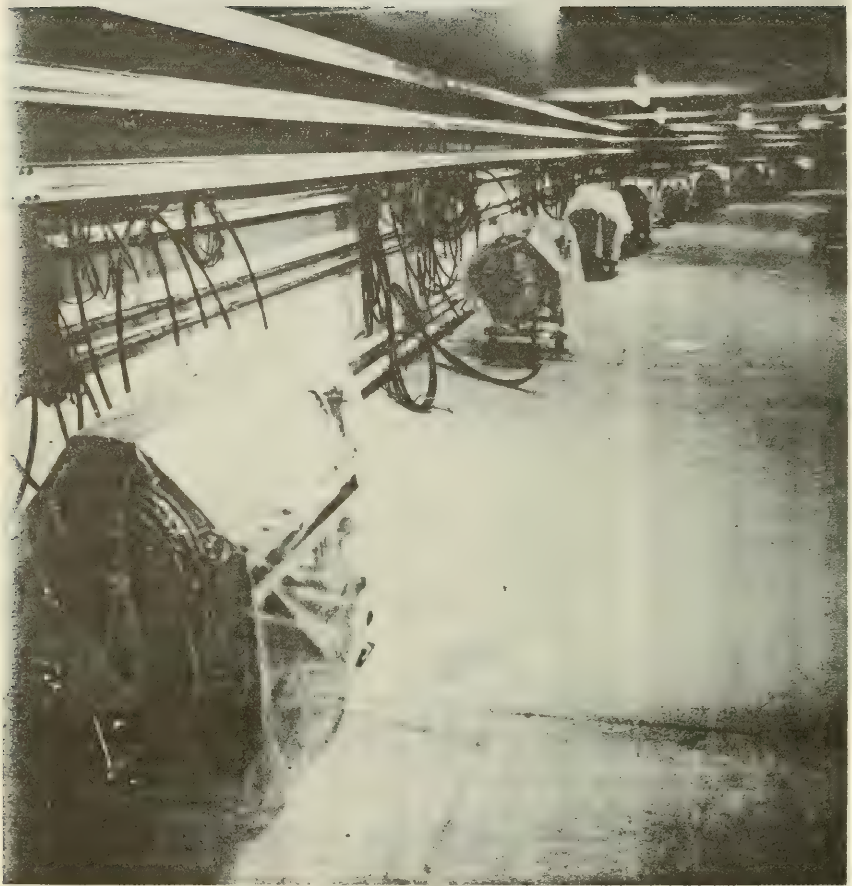
Installation of new precast hoops in the Main Ring at F17. The new Pretarget Enclosure is visible in the background.



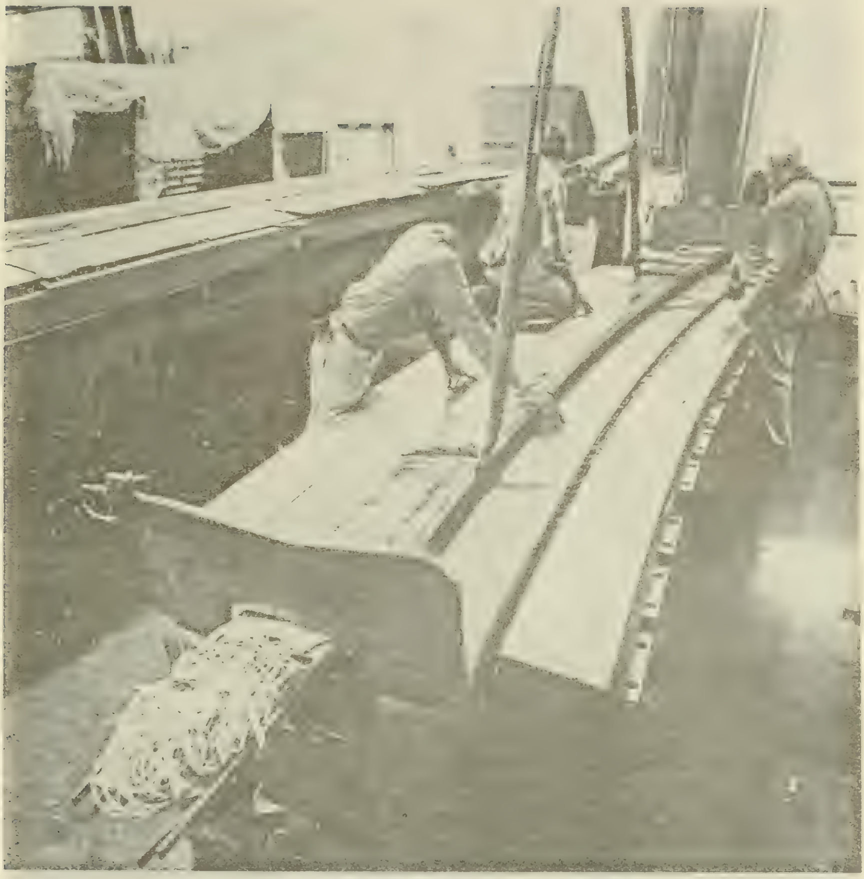
New, larger Main-Ring tunnel sections being lowered into place at location F17. These sections are designed to allow beam extraction for antiproton production.



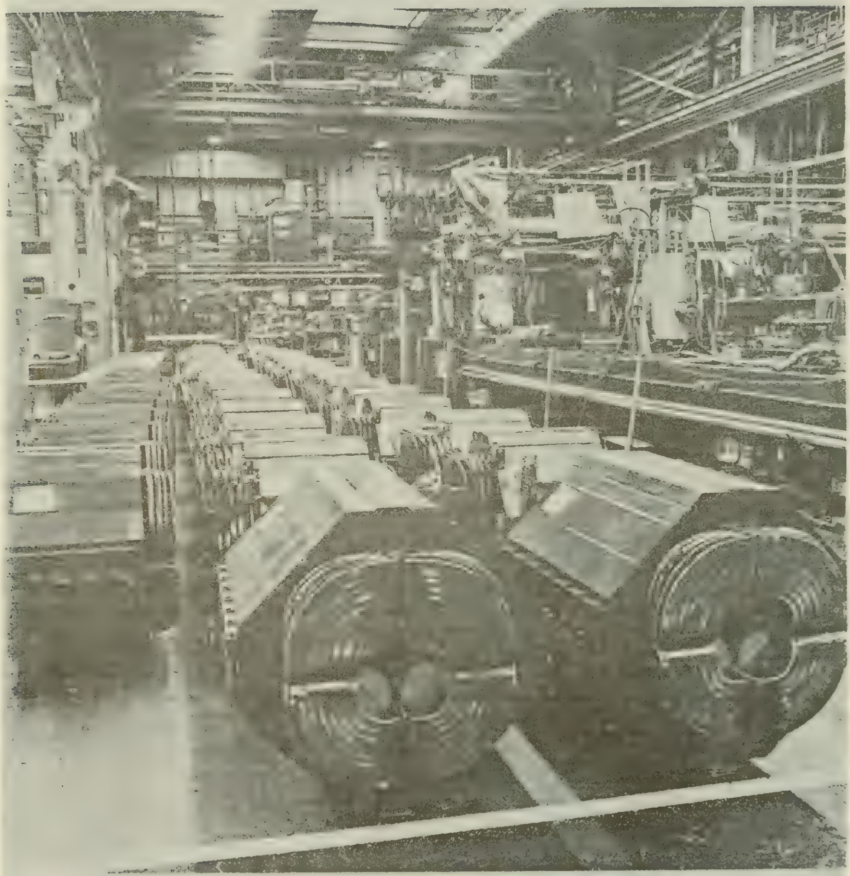
The Antiproton Source tunnel, prior to installation activities.



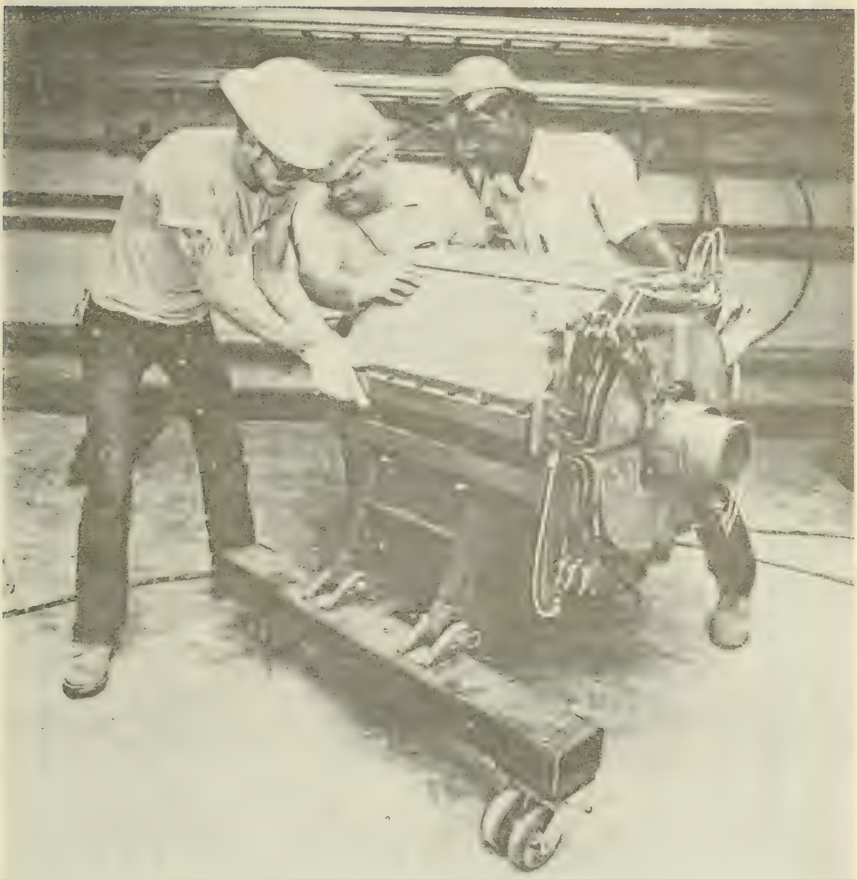
Debuncher quadrupoles installed in the tunnel.



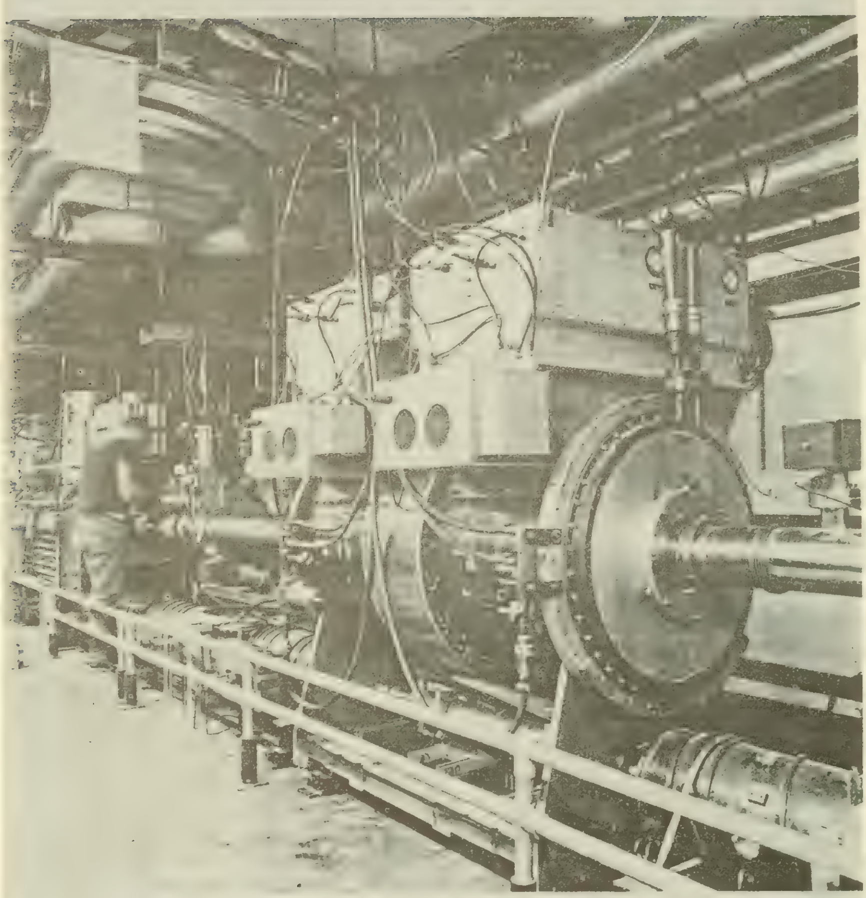
Assembling a large dipole.



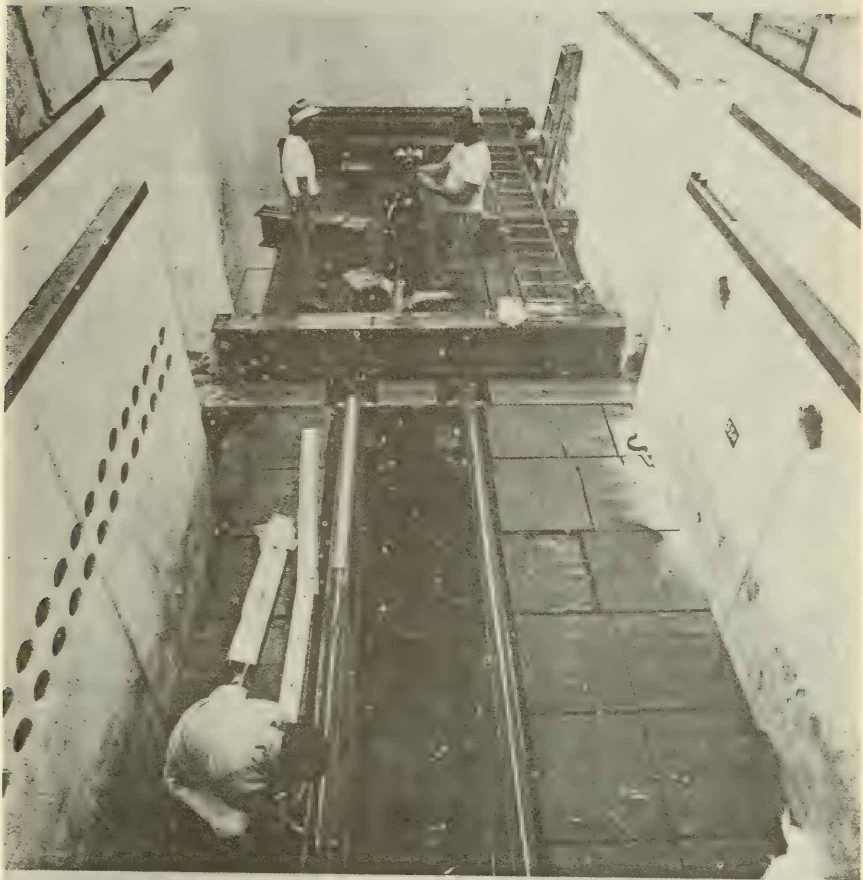
Completed quadrupoles in the Magnet Facility.



A quadrupole being installed in the tunnel.

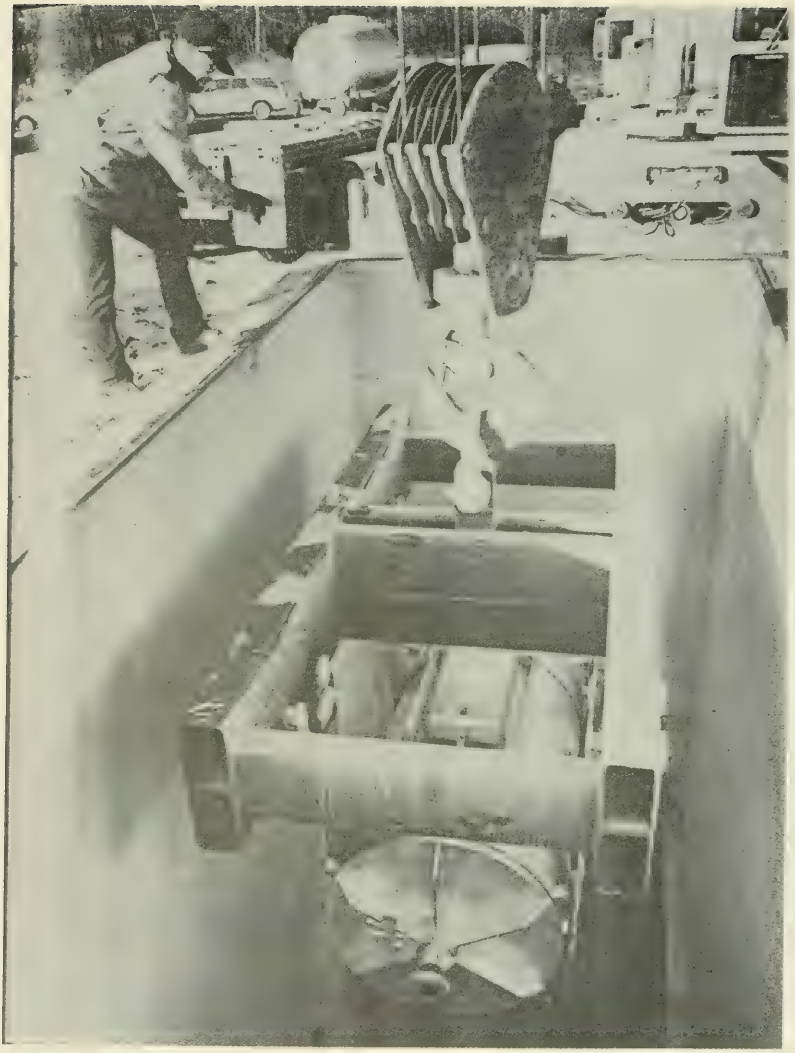


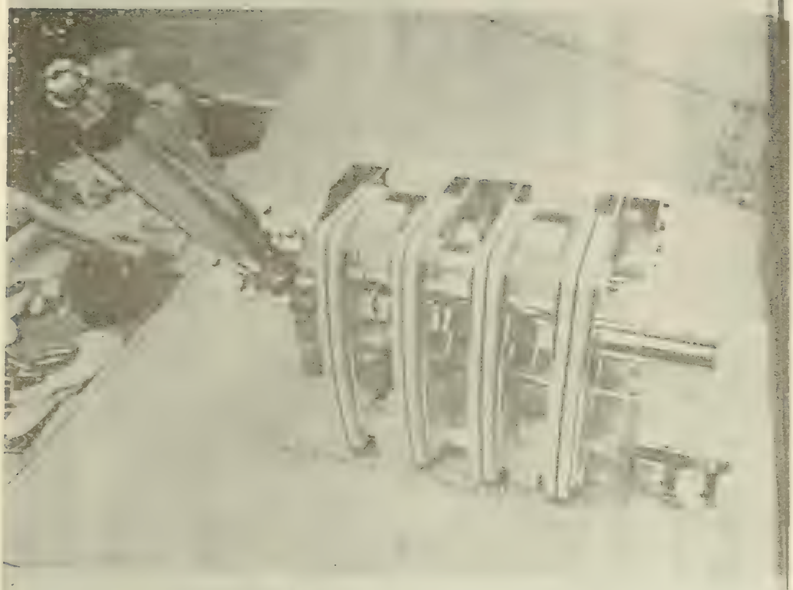
A Princeton-Pennsylvania Accelerator coalescing cavity installed in the Main Ring.



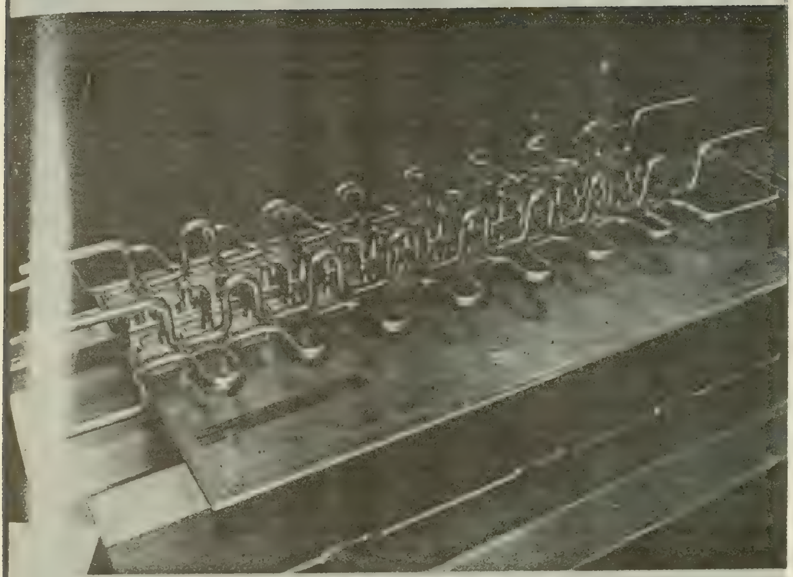
Building the shielding around the antiproton-production target.

A 53-MHz rf cavity being lowered into the tunnel.





The beam shutter for the Accumulator.



A stochastic-cooling pickup.

Joel Moss checking dimensions on [illegible] cavity in the manufacturer's shop.

Lee Brown installing the first conductors in a lithium lens.

III. Fixed-Target Physics at 800 GeV

With commissioning of the Tevatron, Fermilab possesses the highest energy particle beams in the world. The challenge now is their full utilization. In anticipation of this challenge, a large number of new facilities, under the rubric TeV II, have been constructed, with more on the way. Completion of the construction program is expected within a year. There exist several new beam lines and their ancillary enclosures, as well as new experimental halls, such as the splendid new Muon Lab.

Already some of the higher-energy beams have been used, and new physics results are beginning to emerge. In this report, we review recent accomplishments in this "fixed-target" program and describe experiments in progress and others yet to come.

Physics Goals

The research of the past two decades has led to the remarkably successful picture of fundamental forces (strong, electroweak) and constituents (up, down, charm, strange, bottom, top quarks) comprising the standard model. An apparently solid framework now exists for going further and attacking the great unanswered questions remaining before us, such as the origin of elementary particle masses. Most of the TeV II program concerns this standard-model framework — how strong and solid is it? We need not just the existing skeleton, but also all the vital elements that turn it into a complete structure. The basic parameters of electroweak theory need to be precisely found. The theory of strong interactions, quantum chromodynamics, is far from developed and its implications on how hadrons are built up from constituent quarks not well enough worked out. The heavier charm and bottom quarks are especially valuable here, and the Fermilab beams produce an enormous number of them. CP violation, which goes to the heart of the deep, unanswered questions, is being studied in TeV II beams, as well as pursuits of other phenomena which seem to lie beyond the standard model.

New Capabilities

It is important to realize that the energy improvement of the Tevatron means much more than just a factor of two in laboratory energy, or a 40% increase in center-of-mass energy. This occurs for several reasons:

1. First of all, in going from 400 GeV to 800 GeV laboratory energy, one is crossing the threshold for production of systems containing bottom quarks. At the higher energy, the cross sections are expected to be between a factor of 5-10 greater than at the previous energies.
2. There is a major improvement in flux in the secondary hadron beams. This comes about because the higher energy superconducting transport lines accept a much larger bite in transverse momentum than was the case at lower energy.
3. There is a large improvement in duty factor, which used to be 1 second out of every 10 or 15 seconds. In present running it is about 20 seconds per minute.
4. The extra two-thirds of a unit of rapidity which is available in produced phase space at the higher energies allows better separation of the various fragmentation regions for ordinary processes. In particular, there is emergence of the "central plateau" separating the target and projectile fragmentation regions. This is important for studies which attempt to sort out production mechanisms and especially relevant for A-dependence studies.
5. The larger Lorentz factor for particles with short lifetimes, e.g., charm, can be useful in helping to sort them out from the collision debris.
6. While one might expect a lower flux for neutrino experiments because of the longer cycle time at the Tevatron, this is essentially compensated by the rise in the total cross section and the improvement in acceptance due to the smaller angular divergence of the neutrino beam.

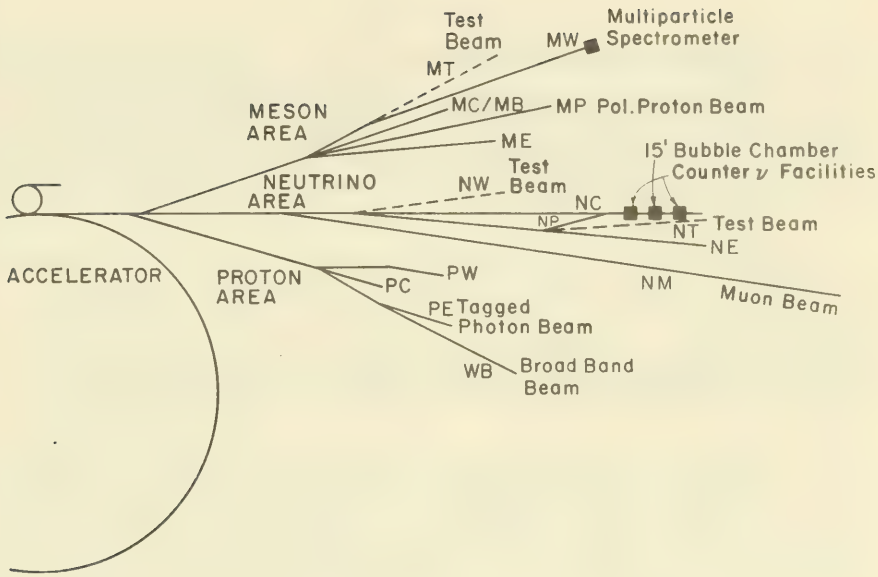


Figure 1. Fermilab secondary beams and the locale of experiments.

Thus, for all of these reasons one may expect a qualitatively different situation at the Tevatron than has existed in previous machines, either the SPS or the Fermilab Main Ring.

The existing fixed-target program is a very broad one, comprising about two dozen approved experiments. About a dozen of these will be on-line in the coming year. While these experiments cover a diverse set of topics, they can be roughly categorized into the following groups: heavy quarks, lepton-induced processes, hard collisions, and tests of QCD. There are, in addition, studies of weak decays and magnetic moments, and strong-interaction studies using polarized beams of p and $\bar{p}$. Table I exhibits the experimental program. The experiments in progress are classified into these categories. Figure 1 shows their location in the fixed-target area.

In the following sections, we will look at experiments by category, irrespective of their status in time; thus, we look both at recent results and future programs.

Table I

Glossary of Approved Experiments in the Fermilab Fixed-Target Program

Electroweak

E-632 WIDE BAND NEUTRINOS IN THE 15 FT BUBBLE CHAMBER (Berkeley, Birmingham, Brussels, CEN/Saclay, CERN, Fermilab, Hawaii, IIT, Imperial College, MPI/Munich, Oxford, Rutgers, Rutherford-Appleton, Stevens, Tufts)

E-635 SEARCH FOR AXION-LIKE OBJECTS (Fermilab, VPI)

E-636 STUDY OF BEAM DUMP PRODUCED NEUTRINOS (Beijing, Brown, Fermilab, Haifa, Indiana, MIT, ORNL, Seton Hall, Tel-Aviv, Tennessee, Tohoku, Tohoku Gakuin)

Table I Continued

E-646 STUDY OF PROMPT NEUTRINO PRODUCTION (Berkeley, Columbia, Fermilab, Hawaii, Rutgers)
E-649 NUCLEON STRUCTURE FUNCTIONS AT HIGH Q^2 (Fermilab, MIT, Michigan State)
E-652 NEUTRINO PHYSICS AT THE TEVATRON (Chicago, Columbia, Fermilab, Rochester)
E-665 MUON SCATTERING WITH HADRON DETECTION (Argonne, Cracow, CERN, Fermilab, Freiburg, Harvard, Maryland, MIT, MPI/Munich, San Diego, Washington, Wuppertal, Yale)
E-733 NEUTRINO INTERACTIONS WITH QUAD TRIPLET BEAM (Fermilab, Florida, MIT, Michigan State)
E-744 NEUTRINO PHYSICS WITH QUAD TRIPLET BEAM (Chicago, Columbia, Fermilab, Rochester)
E-745 NEUTRINO PHYSICS WITH QUAD TRIPLET BEAM (Beijing, Brown, Fermilab, Haifa, Indiana, MIT, Nagoya, ORNL, Tel-Aviv, Tennessee, Tohoku, Tohoku Gakuin)

Decays and CP

E-621 MEASUREMENT OF η_{+-0} (Michigan, Minnesota, Rutgers, Wisconsin)
E-721 CP VIOLATION (Arizona, Athens, Duke, McGill, Northwestern, Shandong)
E-731 MEASUREMENT OF ϵ'/ϵ (CEN/Saclay, Chicago, Elmhurst, Fermilab, Princeton)

Heavy Quarks

E-653 HADRONIC PRODUCTION OF CHARM AND B (Aichi, Carnegie-Mellon, Chonnam, UC/Davis, Gifu, Gyeongsang, Jeonbug, Kobe, Korea, Nagoya, Ohio State, Okayama, Oklahoma, Osaka City, Osaka Sci. Ed. Inst., Sookmyong Womans, Toho, Won Kwang)
E-687 PHOTOPRODUCTION OF CHARM AND B (Colorado, Fermilab, Illinois, INFN/Frascati, INFN/Milano, U. Milano, Northwestern, Notre Dame)
E-690 STUDY OF CHARM AND B PRODUCTION (Columbia, Fermilab, Massachusetts, Mexico)
E-691 PHOTON PHYSICS WITH TAGGED PHOTON SPECTROMETER (UC/Santa Barbara, Carleton, CBPF/Brazil, Colorado, Fermilab, NRC/Canada, Oklahoma, Sao Paulo, Toronto)
E-705 CHARMONIUM AND DIRECT PHOTON PRODUCTION (Arizona, Athens, Duke, Fermilab, McGill, Northwestern, Shandong)
E-743 CHARM PRODUCTION IN PP COLLISIONS (Aachen, Brussels, CERN, Duke, Fermilab, Florida State, Coll. of France, Kansas, LPNHE/France, Michigan, Michigan State, Mons, Notre Dame, Strasbourg, Vanderbilt)

Hard Collisions

E-605 LEPTONS AND HADRONS NEAR THE KINEMATIC LIMIT (CERN, Columbia, Fermilab, KEK, Kyoto, Saclay, SUNY/Stony Brook, Washington)
E-672 HIGH P_T JETS AND HIGH MASS DIMUONS (Arizona, Caltech, Chicago Circle, Fermilab, Florida State, George Mason, Indiana, Maryland, Rutgers, Serpukhov)
E-683 PHOTOPRODUCTION OF HIGH P_T JETS (Arizona, Fermilab, Lehigh, Rice, Vanderbilt, Wisconsin)
E-704 EXPERIMENTS WITH POLARIZED BEAM FACILITY (Argonne, Austin, UC/Berkeley, Fermilab, KEK, Kyoto, LAPP/France, LBL, Northwestern, Rice, Saclay, Serpukhov, Trieste)
E-706 DIRECT PHOTON PRODUCTION (Delhi, Fermilab, Michigan State, Minnesota, Northeastern, Pennsylvania, Pittsburgh, Rochester, Rajasthan)
E-711 CONSTITUENT SCATTERING (UC/Davis, Fermilab, Florida State, Michigan)

Others

E-466 NUCLEAR FRAGMENTS (Argonne, Chicago, Chicago Circle, Purdue)
E-508 EMULSION MULTIPARTICLE PRODUCTION (Cracow, Louisiana State, Tashkent)
E-524 EMULSION/PROTONS GREATER THAN 500 GEV (Washington)

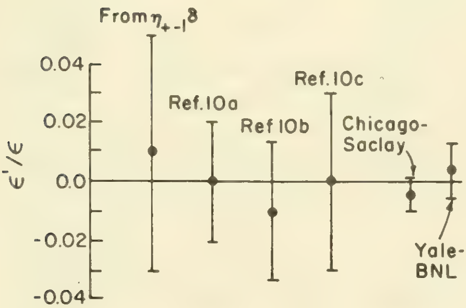
Table I Continued

E-576 EMULSION/500 GEV PROTONS (Belgrade, Fermilab, Lund, Lyon, Nancy, Ottawa, Paris VI, Santander, Strasbourg, Valencia)
E-750 EMULSION/MULTIPARTICLE PRODUCTION (Delhi)
E-751 EMULSION/1 TEV PROTONS (SUNY/Buffalo)
E-753 CHANNELING STUDIES (Bell Northern Research, Chalk River, Fermilab, New Mexico, SUNY/Albany)
E-754 CHANNELING TESTS (Case Western Reserve, Fermilab, GE R&D Center, Sandia, SUNY/Albany)

Weak Decays and Magnetic Moments

Perhaps the most important recent result from Fermilab is the measurement (E-617) of ϵ'/ϵ shown in Fig. 2. The result is consistent with zero and begins to put constraints on the standard Kobayashi/Maskawa-plus-penguin picture of CP violation. The theoretical uncertainties are large and one cannot claim disagreement with theory at this time. Perhaps the main result of this measurement is to decrease, if not eliminate, the theoretical hubris surrounding the attempts to calculate or minimize uncertainties in the long-distance contributions to the $K\bar{K}$-mixing phenomenon. Also shown in Fig. 2 is the recent Yale/Brookhaven measurement, which also shows consistency with zero. The E-617 group is now rebuilding their apparatus and will soon embark on new measurements (E-731) using the same technique. The anticipated improvements in the control of both systematic and statistical errors should considerably reduce the uncertainty in the result.

A highlight of the Fermilab program for many years has been the systematic measurement of the polarization of leading hyperons together with measurements of their magnetic moments. This program is nearly complete at this time, as shown in Table II. There is, let us say, agreement to within 10-15% with the quark-model predictions. The accuracy of the



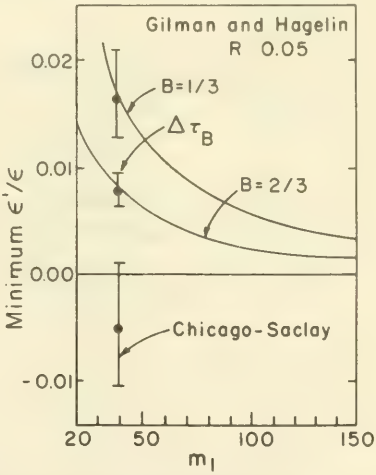


Figure 2. Comparison of measurements of the CP violation parameter ϵ'/ϵ and theory.

measurements has reached a point where the comparisions are dominated by theoretical systematic errors rather than experimental ones. It remains to be seen how much these can be beaten down by theorists in the future.

There has been a nagging discrepancy with the standard model in old measurements of the electron asymmetry in the β-decay of polarized Σ^- hyperons. A new Fermilab experiment (E-715) has very beautifully remeasured this quantity, and the results have been reported. They are shown in Fig. 3. Whereas the old measurements disagreed with Cabibbo theory in magnitude and sign, the new measurement is decisively in accordance with the predictions. Had this not occurred, there would have been mass suicide in the theoretical community. It would have been very hard to accommodate the old results within the standard picture.

Another CP measurement is underway at Fermilab. A group from Michigan, Minnesota, Rutgers, and Wisconsin (E-621) is attempting the ambitious, difficult task of measuring CP violation in the three-pion decays of the K_S and K_L; in other words, to measure η^{+0}. This experiment, which uses a double beam technique, has been set up and has taken some test data. Production running will commence in the next running period. The experimentalists hope to reach the 10^{-3} level, where there is expected to be an effect. However, the problems of systematic errors are difficult, and it remains to be seen how close they really will get.

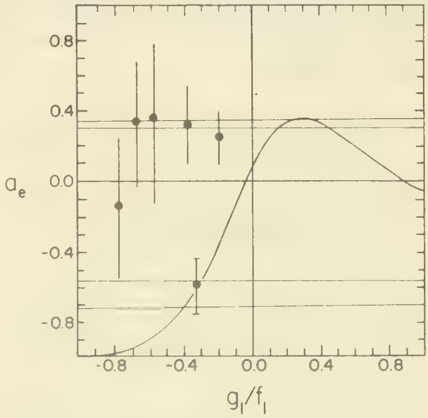


Figure 3. Comparison of measurements of the electron asymmetry in Σ^- β-decay with theory.

Table II

Baryon Magnetic Moments[a]

Baryon	Experimental μ, units $e^+\hbar/2m_pc$	Quark Model Prediction	μ-μ_Q	g/2-1
p	2.7928456 (11)	input	—	1.79
n	−1.91304184 (88)	input	—	—
Λ	− 0.6138 ± 0.0047	input	—	—
Σ^+	2.357 ± 0.012	2.67	− 0.30 ± 0.01	2.00 ± 0.014
$\lvert\Sigma^0 \to \Lambda\rvert$	$1.82^{+2.5}_{.81}$	− 1.63	$-0.19^{+.28}_{-.18}$	—
Σ^-	− 1.151 ± 0.021	− 1.09	− 0.06 ± 0.021	0.47 ± 0.03
Ξ^0	− 1.253 ± 0.014	− 1.43	+ 0.18 ± 0.014	—
Ξ^-	− 0.69 ± 0.04	− 0.49	− 0.20 ± 0.04	− 0.03 ± 0.05

a) Data from Rev. Mod. Phys. 52, S1 (1980), except for μ_{Σ^+}, μ_{Σ^-}, μ_{Ξ^0}, and μ_{Ξ^-}
± (10-15)% agreement with quark model

Electroweak Parameters

Neutrino physics by now has become a rather mature subject, with a demanding level of precision. Recent results (E-616) from the CCFRR group on structure functions are shown in Fig. 4. They show that the QCD scale parameter Λ is beginning to be determined quantitatively, although there is still some way to go. This is best shown in Fig. 5, which exhibits measurements of total cross section. The linear rise with energy is well verified, but there are also clear systematic differences between the set of measurements of CCFRR and their European competition, CDHS. Thus the business of precision measurements in neutrino reactions still has a way to go when pushing beyond the 10% error level of accuracy. The downstream neighbor (E-594) of the CCFRR experiment, one which emphasizes neutral current physics, has also reported new data (Fig. 6). The ratio of x-distributions from neutral currents to those for charged currents are seen to be independent of the scaling-variable x as expected from standard electroweak theory. Some typical events from this fine-grained calorimeter are shown in Fig. 7. Both experiments also measure the ratio of neutral current to charged-currect cross sections. The numbers are shown below, along with the new result from the neutrino-electron scattering experiment at Brookhaven:

$\sin^2\theta_W = 0.242 \pm 0.010 \pm 0.005$ CCFRR
$0.243 \pm 0.014 \pm (\sim 0.014)$ FNMM (preliminary)
$0.209 \pm 0.029 \pm 0.013$ BNL

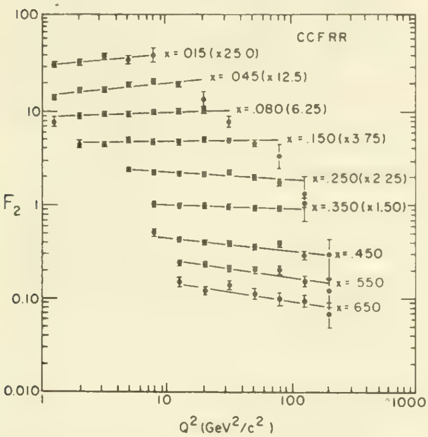


Figure 4. Structure function F_2 as measured by the CCFRR group at Fermilab.

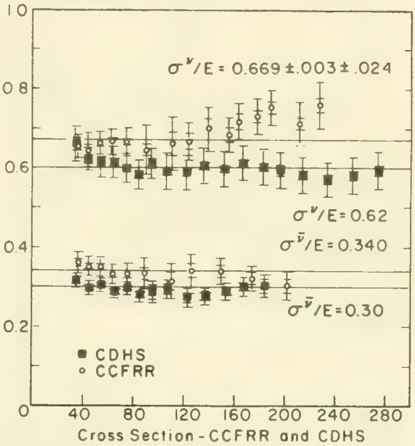


Figure 5. Neutrino total cross sections as measured by CCFRR and CDHS.

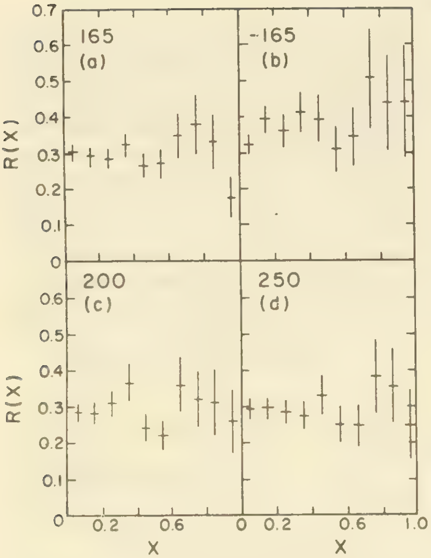


Figure 6. Dependence on scaling variable x of the ratio of neutral-current and charged-current structure functions as measured by the FNMM group (E-594) at Fermilab.

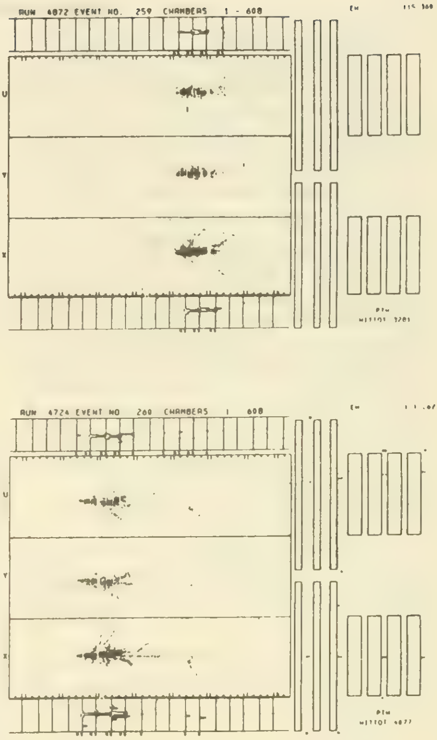


Figure 7. Typical events as seen in the FNMM calorimeter. →

QCD and Hadron Structure

Cross section measurements in neutrino beams impinge as much on QCD properties as on electroweak theory. We have already mentioned Λ determinations from charged-current data. CCFRR has measured rather well the structure function xF_3 as shown in Fig. 8. Especially interesting to me is the determination of the Regge asymptotics at small x, and the establishment of the Gross-Llewellyn-Smith sum rule (including QCD radiative corrections). Structure functions from both neutrino-scattering and muon-scattering experiments at Fermilab and CERN are in reasonably good agreement with QCD and with each other. A new round of muon-scattering experiments (E-665) in a vastly improved beam and at much higher energy is being prepared at Fermilab. A large spectrometer using the Chicago Cyclotron Magnet and vertex spectrometer from the CERN EMC experiment is now being installed. The experiment will be commissioned in the 1986 running period. The principal goals of that experiment are the study of the A-dependence of structure functions and of the hadronization process.

We now turn to QCD tests done with incident hadrons. There is quite a variety of them in the program, using many different techniques.

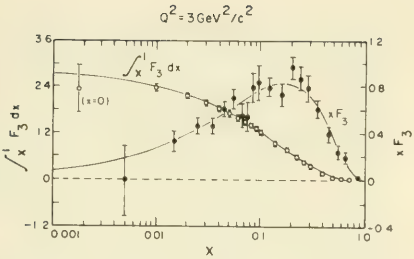


Figure 8. The structure function XF_3 as measured by CCFRR.

Results from E-615, which looks at forward Drell-Yan dileptons, were recently published. It was predicted by Berger and Brodsky that as the Feynman x variable approaches unity, the dilepton angular distribution should change from the usual $1+\cos^2\theta$ behavior toward a $\sin^2\theta$ behavior as a consequence of "higher twist" non-scaling contributions. This is very clearly seen in the data (Fig. 9). Not anticipated by the theorists is a decreasing value of mean transverse momentum of the dilepton in the same limit.

Another new result comes from measurements (E-609) of dijet production from incident pions and protons. The history of jet production in fixed-target experiments has been a checkered one. If one tries to trigger on jets with a total transverse energy trigger, such as done in the collider experiments at CERN, one is swamped by a background from azimuthally isotropic events of very high multiplicity. These events are interesting in their own right, but do not seem to have much to do with simple binary QCD hard collisions. There is, however, increasingly strong evidence that the jets are there, albeit buried in heavy background, and that other triggers which are sufficiently unbiased to be convincing may be used to pull out the jet signal. One successful example demands at least two isolated high-p_T particles above a prescribed p_T threshold irrespective of their azimuthal correlation. This trigger succeeds in producing events of high planarity. Indeed, as the total E_T of the events increase, the planarity increases despite a constant threshold p_T. Thus, by this and other means E-609 has with reasonably convincing arguments produced a differential cross section for inclusive jet production which in fact agrees reasonably well with QCD expectations.

Another interesting result from E-609 is the comparison of the jet production in pion beams relative to proton beams. Another idea of Berger and Brodsky is that some of the time the pion behaves like a point-like particle, when the quark and antiquark of the pion are atop each other and produce no source of gluon field. If this configuration does exist within the pion, then on arrival at the target it may diffractively dissociate into a pair of jets without production of any beam jet. For a proton primary this would be less likely because of the three quarks rather than two. Very preliminary data from E-609 show (Fig. 10) an excess of events in which there is little or no forward

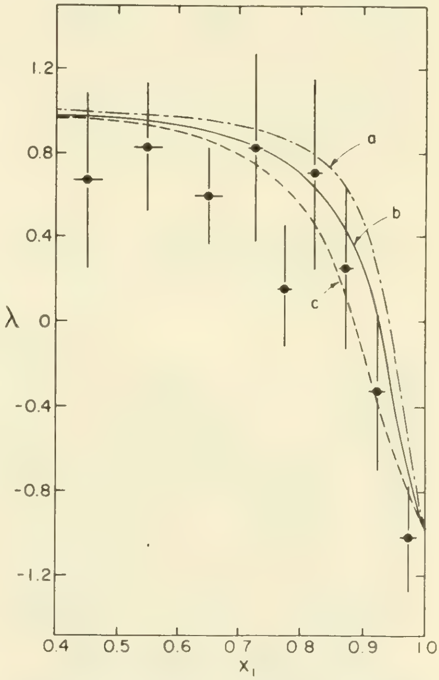


Figure 9. Angular distribution of forward Drell-Yan dileptons as measured by E-615.

"beam jet" energy. Whether this is simply a reflection of the stiffer quark distribution in the pion relative to the proton is not clear at this time and requires considerably more analysis. What is clearly shown is that jet phenomena produced by pion beams differ significantly from those in proton processes.

A variant of this same idea will be pursued by E-683, which uses a photon in the initial state to produce two jets. Half of the time the photon is not "vector-dominated" by ρ, but is, on arrival at the target, believed to be a bare $q\bar{q}$. If that is the case, it can also materialize into a jet pair without any beam jet being produced in the direction of the initial photon. It is this process for which the experimentalists will search. This is a considerably cleaner situation than for pion-induced dijets.

To go further in the study of fixed-target hard collisions will probably require more precisely defined experimental quantities than the rather amorphous objects of 5-10 GeV p_T, which are difficult to accurately define as jets, especially given the very steeply falling production spectrum. One attempt to do this is via measurement of leading dihadrons of high p_T. This is attempted in two experiments: E-605 is a very high resolution spectrometer which observes dihadrons produced symmetrically at 90° in the center-of-mass, with rather small angular acceptance. Complementary to this is E-711, which will look at charged dihadrons without further particle identification but with very large angular acceptance. Experiment 605 has taken data, which is now under analysis. Experiment 711 is under preparation and should run during this running period.

Another attack is to look at direct photons produced in hard collisions. The direct-photon process provides a precise measurement in terms of the yield of inclusive photons as a function of their kinematic angle and transverse momentum. The presence of this electromagnetic particle also makes theoretical calculations easier and less ambiguous. A new experiment (E-706) will not only measure photons with high precision and very large coverage but will also look at the properties of the associated jets.

Yet another approach is to study onia, in particular χ states presumably produced by

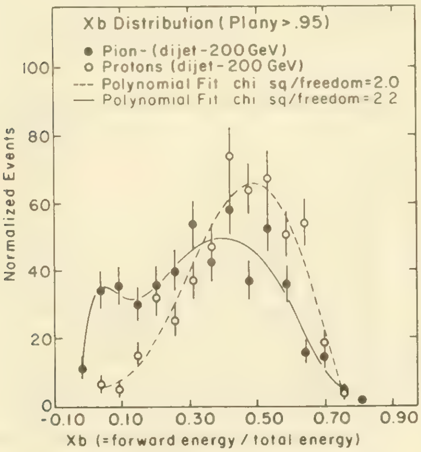


Figure 10. Distribution of the fraction of incident energy contained in the E-609 beam-jet calorimeter.

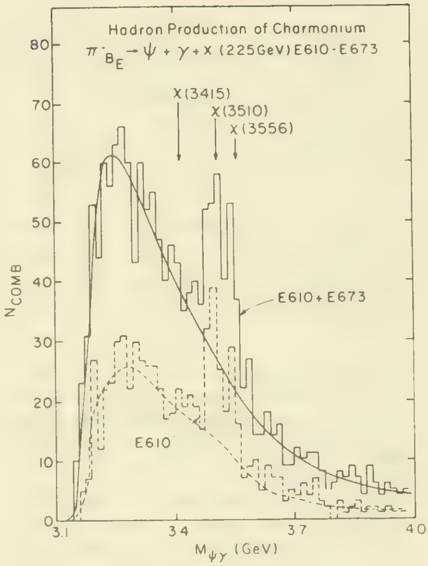


Figure 11. Observation of hadronically produced χ states in E-610 and E-673.

glue-glue annihilation. Limited data (Fig. 11) already exist from Fermilab experiments E-610 and E-673 on this. To my knowledge, the results don't agree very well with simple theories, and in any case a much more extensive data sample will be required to make incisive comparisons. Experiment 705, now being set up, will do this and should increase the sample of χ states decaying into $\psi\gamma$ by an order of magnitude.

The precursor of this experiment (E-537) produced very good data on antiproton annihilation on heavy targets into dimuons. From this process, one may quite directly determine the valence-quark structure of the projectiles. Figure 12 shows the resulting x distribution of quarks in the antiproton together with QCD comparisons. The agreement is quite satisfactory.

An additional experiment which will probe the dynamics of hard collisions is E-672, which will observe hadrons in association with ψ and Drell-Yan dilepton production. In addition, E-704 will examine a variety of soft and hard processes with incident polarized protons and antiprotons. Polarized-beam and polarized-target experiments are a very good constraint on theoretical model building. There is nothing which ensures the continued humility of theorists as well as measurements of polarization phenomena. Theorists who successfully explain unpolarized data are often brought to their knees when the polarization information comes in.

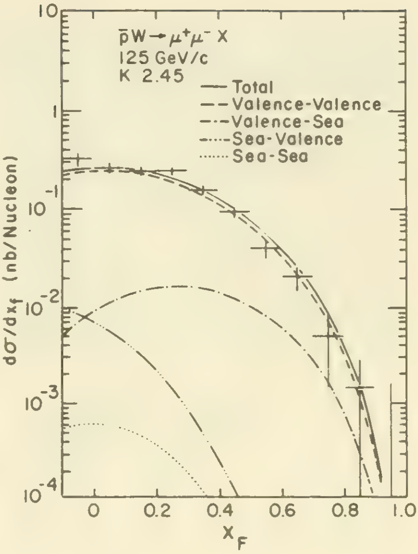


Figure 12. Valence-quark structure function as determined from $\bar{p}$ induced Drell-Yan dileptons (E-537).

Heavy-Quark Physics

In principle, prospects for charm and bottom physics at a fixed-target hadron machine are great. Given 10^{11} interacting hadrons per experiment, one may expect a yield of 3-million produced $b\bar{b}$ and 100-million produced $c\bar{c}$ pairs. This easily exceeds the world production of such quantities in e^+e^- collisions from now into the foreseeable future — including Z factories such as LEP and SLC. Of course the problem is signal-to-noise. In addition to all those bottom and charm quarks, there is a tremendous number of ordinary ones produced as well. Whether a fixed-target program in heavy-quark physics can compete with e^+e^- colliders is therefore a serious issue. I think it is too early to tell what the ultimate situation will be. But I do feel that there is real cause for optimism in the case of hadron machines, and that there is good reason to fight the good fight against the evil background to the bitter end. In terms of technique, there is at least one advantage of hadron machines, in that one may see the vertices of the events better than one does in e^+e^- processes. This is sure to help on an event-by-event basis, where one may hope to unscramble which track came from which vertex in a better way than can be done in a collider.

The physics case for looking at heavy quarks produced in hadron beams goes beyond simply the possibility of being able to find more than one finds in e^+e^- collisions. There is the possibility of having a greater variety of hadrons containing heavy quarks to study. In particular, baryons may well become much more interesting as the properties of mesons are flushed out and well determined by the e^+e^- colliders.

In terms of understanding strong interaction dynamics, baryon structure may be a more crucial test than the rather boring two-body potentials which one uses for the mesons. If there are strings connecting quarks, do they imply intrinsic three-body forces as well as pair forces within a baryon? Table III shows the variety of different kinds of mesons and baryons one may hope to see. Already there is some evidence for the usc and ssc baryons. Some of my other favorites are the ccd and possibly ccs. Further down the list, one has to be optimistic in hoping that one can find them in hadron beams, but things such as the bcd or bss would be most interesting to find. The b$\bar{c}$ meson should also be interesting to observe. It is not clear whether e^+e^- or hadron machines are a better way to make it — it's not easy for anyone.

What is important about the physics of charm and bottom? In the case of hadron collisions, production dynamics should teach us more about QCD. It is simply not understood at present. Normalization and energy dependence of the cross section, A-dependence of the cross section, x-dependence of the cross section, and beam dependence of the cross section are only a few of the major uncertainties. Beyond QCD production dynamics, the spectroscopy and decay properties are of great interest. In particular, the bottom quark is especially beautiful. Its long lifetime implies that it undergoes in some sense a forbidden decay. Therefore the b

Table III

Catalogue of $Q\bar{Q}$, Qgq, QQq, and QQQ States of Future Interest

Particle	Number Produced in Typical Experiment	Comments
c$\bar{u}$	$\sim 18^8$	Bread and butter
c$\bar{s}$	10^7	
b$\bar{u}$	$\sim 3\times10^5$	Learn from CESR/
b$\bar{s}$	3×10^4	DORIS what to do
b$\bar{c}$	3×10^3?	Possible?
cud	$\sim 10^7$	Large samples
cuu		should be found
cdd		
usc	$\sim 10^6$	Found already
ssc	10^5	
bud	$\sim 3\times10^4$	Find them!
buu		
bdd		
ccd	$\sim 10^4$	Possible?
ccs	$\sim 10^3$	
bus	$\sim 3\times10^3$?	Marginal
bss	300?	
cub	300?	
bcs		Prayers required
ccc		
bcc		
bbc		
•		
•		
•		

should be more sensitive to rare, hidden phenomena. That is, the branching ratio associated with a rare process will be larger for bottom than for other quarks simply because the total width is smaller. In the field of b-decays, the e^+e^- colliders at present are far ahead. But in the long run it may be important to study a variety of weak decays of bottom (and charm) particles for the same reason it was important for the strange system. The basic parameters, such as Cabbibo angles, were determined through a variety of experiments, not just a single one. Overdetermination of these parameters make their measured values more credible. In the case of heavier quarks, one believes that simple spectator and/or "factorization" models should be more reliable. Nevertheless, there have already been surprises in the charm system, and surprises in the bottom system are not yet ruled out. The more measurements that become available, the greater can be our confidence in determining the very important basic parameters of the standard model.

What have hadron beams provided us in charm and bottom physics thus far? In bottom physics, it of course gave us the γ itself. But beyond onia, there is not much at all. In charm physics, information on lifetimes has been found from a variety of experiments, most of which originated in hadron beams using high-precision vertex detectors such as nuclear emulsion or bubble chambers. In Fig. 13 a recent summary of these determinations is given. In terms of the number of reconstructed charm particles per exclusive decay channel, hadron-induced processes were until recently competitive with e^+e^--induced processes. As an example, in a photoproduction experiment at Fermilab (E-516) (see Fig. 4), very clear D^* signals have been seen (Fig. 14). Another intriguing result has been reported by E-623. It is a byproduct of a search for η_c decay into $\phi\phi$. Within a data sample containing 4 charged kaons, evidence has been found for the Cabbibo forbidden decay of D^+ into $\phi\pi$, as shown in Fig. 15. There are about 240 entries in the peak, which regrettably suffers from a very biased trigger because of the nature of the $\phi\phi$ search. Surprising is the absence of a corresponding F nearby, since the branching ratio for F to $\phi\pi$ is a few percent, as measured by e^+e^- collider experiments. One might expect the production cross section ratio F^+/D^+ to be of the order of 10%. Thus a comparable F peak might have been seen. However, the experimentalists caution that because of the bias in the trigger, one should not draw strong conclusions about the relative production of F to D from this measurement. Low-statistics evidence for compar-

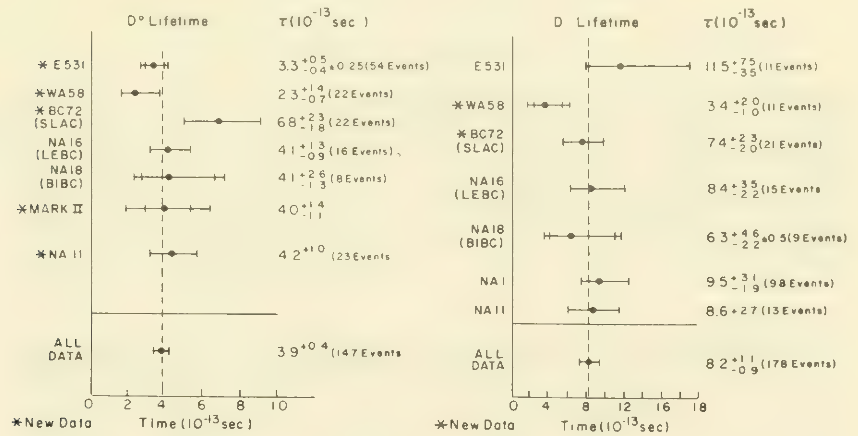


Figure 13. Status of D^+ and D^0 meson lifetime measurements.

able strengths of F and D production does exist from the ACCMOR experiments NA11/32 at CERN. In any case, this $\phi\pi$ decay mode looks very promising for future studies of charm, in particular for comparison of the relative production dynamics of F and D in hadron collisions.

The upcoming program in charm physics at Fermilab contains several experiments. In the forthcoming running period, E-691, a continuation of tagged-photon photoproduction, will utilize a transverse energy trigger which ought to enhance the charm signal. Silicon strip vertex detection has been added as well. Experiment 653 will use protons incident on an emulsion-plus-silicon-strip target followed by a multiparticle spectrometer of high resolution. With use of the downstream spectrometer, vertices in the emulsion may be located with sufficient accuracy to allow scanning of the events to be done in a reasonable length of time. Both these experiments promise to yield between 100 and 1000 reconstructed charms per "easy" exclusive channel.

In addition, the "little European bubble chamber" LEBC has moved to Fermilab and will take data this year (E-743) in conjunction with the Fermilab multiparticle spectrometer. This experiment should yield quite unbiased cross-section measurements of charm production in hydrogen. In addition, two high-resolution bubble chambers (E-632, E-745) will take data this run in the neutrino beam. A sizeable charm sample should be seen.

Further down the line is E-690, an ambitious enterprise which will utilize a sophisticated on-line fast-trigger processor. Events will be reconstructed on-line by the processor, and a search will be made for exclusive channels. These will then be selected; those with charm candidates (or other options) will be retained for later analysis. A smaller version of this experiment is now running at Brookhaven. After the processor is proven there, the experiment will be moved to Fermilab, probably within a year or so.

Finally, a second-generation broad-band photon beam experiment (E-687) will soon be set up. The spectrometer used in this experiment promises to be as powerful as any at Fermilab, and it will be a very strong facility for charm and bottom studies in the future. It can operate not only in photon beams but also a variety of hadron beams.

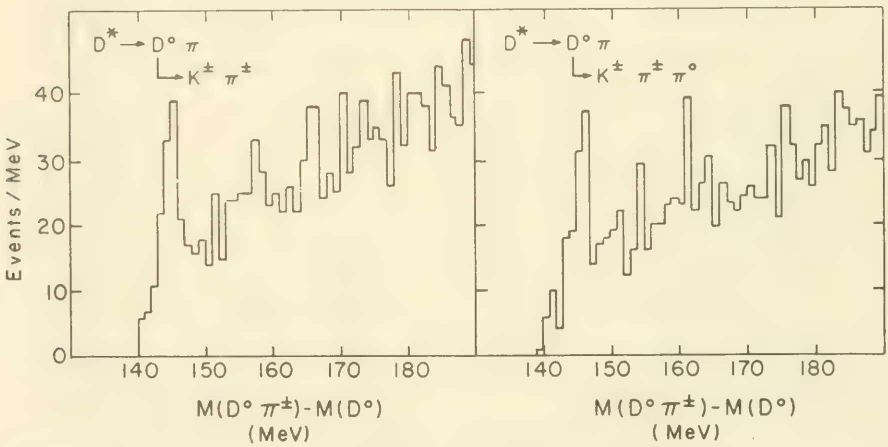


Figure 14. D* signal measured in the E-516 photoproduction experiment.

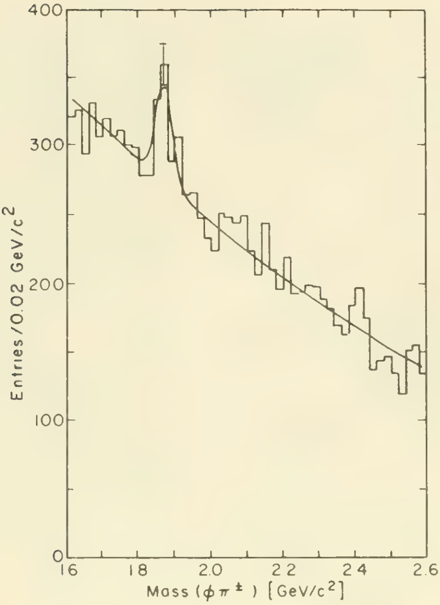


Figure 15. The Cabibbo-forbidden decay $D \to \phi\pi$ observed in E-623, designed to search for $\eta_c \to \phi\phi$.

Beyond the Standard Model

In general, the Tevatron fixed-target program must be said to be programmatic. That is, it deals mainly within the standard model with phenomena which need to be better understood and parameters which need to be better measured. But there do exist discovery opportunities which go beyond the standard model. One of these is the long-standing problem of same-sign dilepton production by neutrinos. In several experiments, it has been found that the process

$$\nu N \to \mu^- \mu^- X$$

occurs at a rate too high to be easily explained by conventional sources of background. A new measurement, using the Fermilab 15-ft bubble chamber (E-53) has been made of the very closely related process $\nu N \to \mu^- e^- X$. This process is not seen at the level of observation claimed for same-sign dimuon production. This may indicate either that the same-sign dimuon effect is spurious or that the effect is real, but violates the μe universality. This latter hypothesis need not be considered too radical if indeed something crazy is the source of the phenomenon. Because the purported $\mu^-\mu^-$ signal appears to increase with energy, the forthcoming neutrino running with 800-GeV primary protons should have much higher sensitivity to this process.

Another possibility of discovery physics has been stimulated by the observation of the ζ at DESY by the Crystal Ball collaboration. I am not fully convinced that the phenomenon has gone away, despite the negative second-round results, because to my knowledge the hypothesis of Tye and Rosenzweig has not been

fully refuted. To me, their model is the most reasonable explanation of the original results. To refute it requires precise knowledge of operating conditions of the machine in both the original run and in subsequent running. (Ideally, one would want to run some fraction of the time at one sigma or so off the resonant peak of the γ on each side in order to be sure that the Tye mechanism is inoperable.) The relevance of this phenomenon to the Fermilab fixed-target program has to do with E-605, already mentioned in connection with high-p_T dihadron production. This is the follow-up experiment to the one which discovered the γ particle. In the next running period, the emphasis will be on high intensity, with observation of dimuons with high mass resolution (20 MeV?). This resolution will be sufficient to resolve cleanly the various upsilon excited states. If there is any ζ-like entity, there is a good chance of seeing it. If Tye and Rosenzweig are right, one might see a first excited state at somewhere around 9 GeV.

Yet another fixed-target experimental program which contains discovery potential is the set of beam-dump experiments (E-635, E-636, and E-646). The bread-and-butter part of that program is direct observation of the tau neutrino and study of its properties. But, beam dumps also provide good opportunities to search for axions, neutral leptons, and the long-lived neutral penetrating particles of supersymmetric theories. The monojet events from UA1 provide new stimulus for these kinds of searches, because a reasonable hypothesis for explaining the monojets is decay of the Z into a new neutral long-lived penetrating particle plus the jet.

However, the beam dump program at Fermilab is in trouble. Although there are three approved experiments and a satisfactory dump design (Fig. 16), the facility is expensive. Because of funding shortfalls at Fermilab, it has been decided to defer beam-dump construction in order not to disrupt too much of the remaining program. In order to minimize the delay, the Laboratory and DOE have submitted a line-item construction request for the FY87 high-energy physics budget to fund this facility.

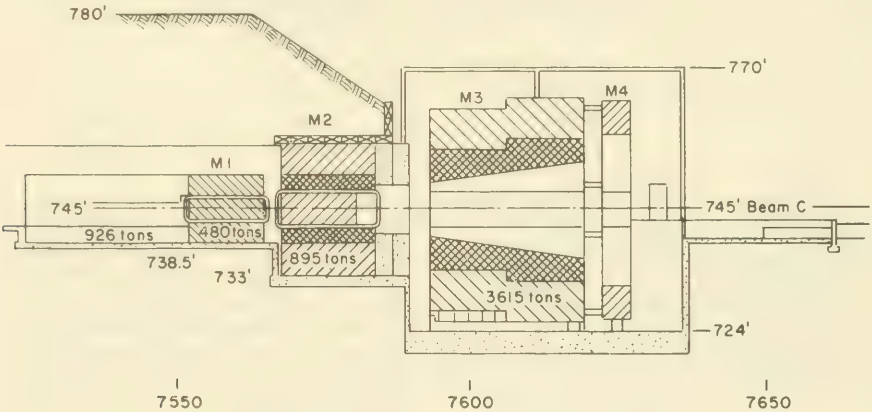


Figure 16. Design for the Fermilab Direct Neutral Lepton Facility.

The TeV II Problem

The status of the beam dump is one example of a general problem (Fig. 17) which the TeV II program faces. As I see it, this problem has a three-fold source. The first source is user perceptions of delays, insufficient Laboratory support, insufficient agency support, competition with TeV I, as well as possibly greater security for the future of a group within a large colliding beam facility. There may also be a physics issue: being behind the high-energy frontier, where the physics is likely to be more programmatic and have less headline-making potential. The source of the delays as seen by the Laboratory is that there is simply not enough money to do the job. And it does not help if the Laboratory, when viewing the user community, sees a flagging of interest or lack of stamina. The third source of the problem comes from the national scene, where funding agencies, HEPAP, and other nationally-based advisory groups may see too many competing demands for funds, given all the collider initiatives here and abroad, as well as underground experiments, and R&D for the SSC. TeV II looks like just one more program competing with all the others, despite its diversity and breadth. Since it is a broadly-based program with many components, it also is a prime candidate for cuts. Anyone looking at the program will have his or her favorite experiment and his or her turkey. (The problem is that a dozen people in a room will find no agreement whatsoever on which experiment is the turkey.) Thus, everyone will agree that something can be cut out of the program without anybody noticing, but no one can agree on how to do it without severe damage, with everyone noticing.

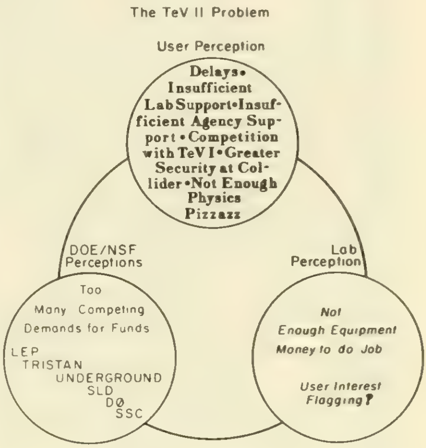


Figure 17. Three-way vicious circle underlying existing problems with the fixed-target program.

Longer Range Opportunities

Such pessimistic words about the fixed-target program should not be taken to indicate that, in fact, the physics is drying out. As we have seen, there is very much to be done. The physics is extremely good and the opportunities are of high quality. In the realm of big initiatives, one of my favorites is a next-generation round of heavy-quark physics. This may require a new spectrometer facility, one which can go an order of magnitude beyond what is hoped for in the upcoming runs. I would like to see 10^4 to 10^5 detected charms per easy channel as the goal. There is a question of how to proceed with such a large initiative — or whether one should proceed. One option is to rely on existing initiatives in the program or new initiatives of comparable scale. The arguments in favor of this are, first, that it would exploit optimally the expertise of existing teams and provide continuity with the programs now going on. Second, the physics with several groups would come out in parallel, with competition providing additional stimulus. And one might not need escalation in group size or apparatus to do the job. One could also cite examples of very big comprehensive spectrometers which haven't done as well as more modest apparatus with greater specificity.

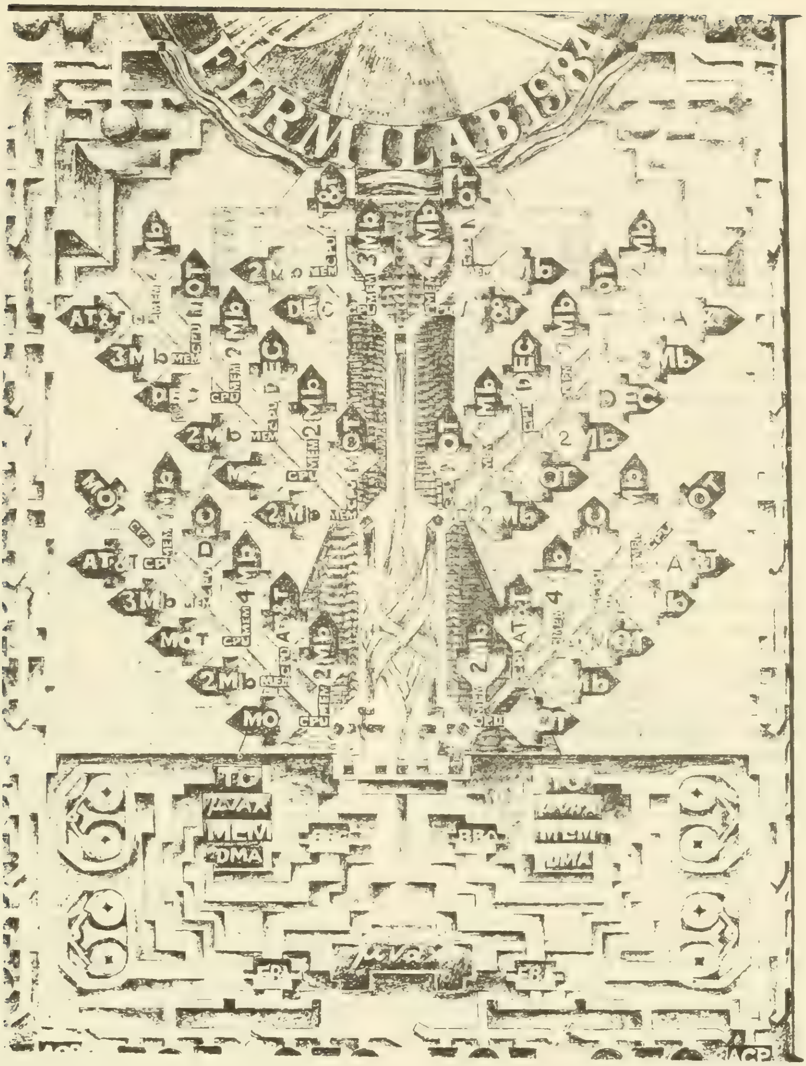
On the other hand, the physics may simply require, just as it has in colliding beams, concentrating most of the effort into a very big centralized facility which might approach collider detectors in size and scope. It may be

arguable that existing groups doing charm and bottom physics are too small, and that the spectrometers which are being built, or exist now, are simply not powerful enough to do this kind of physics. Certainly a necessary condition for physics at this level is that a variety of incident beams should be available, not only protons but also neutrons, mesons, hyperons, and photons as well. One will need to make comparisions, as well as produce a variety of different kinds of hadrons containing heavy quarks. Another argument for a very big facility is its visibility; it is easier for the national community to notice and thus support. Finally, another reason for a large charm-bottom spectrometer may have to do with the SSC. If $200 to $500 million will be spent on detectors for the SSC, there should be a considerable amount of R&D devoted to that enterprise. This R&D must go beyond paper designs and construction of small modules which are put into test beams. Systems which are large enough to capture an entire hadron jet of several hundred GeV (a bread-and-butter phenomenon for the SSC) should be tested. Secondary beams at Fermilab are certainly a very good source of such jets. Certainly Fermilab should provide facilities for this kind of R&D. But, just like all R&D efforts, if there is physics that can be attached to the instrumental development, the whole effort will be better focused, gain more momentum, and in general have greater productivity. Therefore, it seems reasonable that Fermilab, while welcoming detector R&D done in its secondary beams, will welcome even more those initiatives which have a strong physics motivation as well. Therefore, it may make sense to integrate SSC detector R&D into a large heavy-quark spectrometer program.

At the opposite extreme, there are opportunities for small initiatives within the fixed-target program. Examples now discussed or presently pursued include a program on crystal channeling which may even have applications to accelerator physics (including SSC) in providing small septum magnets, measurement of the magnetic moment of Ω^-, quark searches, searches for rare decays such as $\Xi^0 \rightarrow p\pi^-$, searches for anomalons, and soft muon physics. These have obvious sociological importance in this age of giant collaborations. But they must stand on their own in terms of physics quality. I think most do.

There exist more exotic possibilities in fixed-target physics, such as colliding stored antiprotons on gas targets to resonantly produce ψ and χ states, such as done at the CERN ISR. Storing muons and pions in order to make low-energy neutrino beams has also been discussed from time to time. The desirability of doing this depends somewhat on the future of neutrino-mass measurements. Certainly, if neutrino masses and mixings are convincingly found to be non-vanishing there may well be a renaissance of interest in this kind of physics at Fermilab.

In any case, the bottom line on the future of fixed-target physics is one of commitment. Much very good physics is there to be done. The necessary condition is that there be enough people who are willing to do the hard work to get it out.


FERMILAB 1984
AT&T
DEC
MOT
2Mb
3Mb
CPU
MEM
μVAX
MEM
DMA

IV. Fermilab's Advanced Computer Program

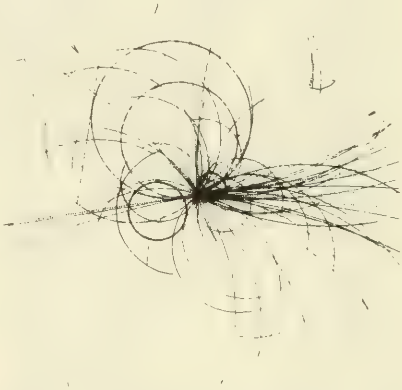
Introduction

By its very nature, experimental basic research has always pressed hard against the existing limits of technology, expanding those limits when necessary and possible. Nature does not release its secrets easily. The challenge of exciting new experimental possiblities frequently lures physicists into technological development areas. A familiar example, Fermilab's leadership in superconducting technology has been motivated by a need for improved accelerators to allow experiments at higher energy. Since the 1930s, electronics and computing have, along with accelerators, been the focus of recurring interest in the high-energy physics community. Among the first to build and use electronic logic gates (ORs and coincidence circuits) were high-energy experimentalists for their detectors. These gates later became the fundamental building blocks of all digital electronics and computers.

In the early sixties, high-energy physics made important early contributions to computer hardware, especially on-line processing. It was also the first field to exploit the very high speed ECL (Emitter Coupled Logic) circuit technology. From that period until recently, commercial computing hardware and system software proved adequate for most of high-energy physics needs and were not a major impediment to progress. No longer is this true. Computing limitations now have severe impact in a number of important areas, affecting the progress of experimental and theoretical efforts as well as new accelerator design.

The biggest demand on Fermilab computing is for what is called experiment event reconstruction. Physicists study the interactions of fundamental particles by producing millions of individual collisions between them, and studying how other particles, the debris, fly off into their detectors. Sophisticated as they are, the experimental detectors provide only the sparest information about where and when these secondary particles passed. To analyze the physics, the physicist needs to know the type of each particle and the momentum and angle with which it emerged from the interaction.

Reconstructing these parameters for each of dozens of particles, for each of millions of collision events, from the bits of detector information recorded during the experiment, requires a monumental scale of computation. Large experiments already measure the amount of time they use on Fermilab's large main frame computers in years. As the energy of accelerators increase, so do the number of secondary particles and of interaction events to be studied. But interesting physics events tend to be rarer.



Bigger haystack, smaller needle: we need advanced computer ideas. In 1982 Fermilab formed the Advanced Computer Program to confront computing problems at the R&D level. This group is known by its initials (ACP). It now has a dozen technical people with backgrounds in experimental and theoretical physics as well as electronic and computer engineering. In its work the ACP interacts strongly with industry and university computer science efforts, mingling ideas and technology from outside of high-energy physics with its own.

For experiments, the ACP goal is simple: remove the mechanics of computing from contributing significantly to the "turn-around time" between the idea for an experiment and the physics conclusions derived from the experiment. Similar motivations apply in the theoretical and accelerator areas. Presently, a major part of this turn-around time is spent by computers carrying out the trillions of elementary calculations required for various

aspects of the research. The ACP has focused its efforts on developing ways to carryout this "number crunching" that are far more cost effective than those available commercially. Studies by ACP people have concluded that we can now attack this problem effectively by creating new computer architectures built out of large numbers of the very powerful VLSI (Very Large Scale Integration) microprocessor circuits being produced by industry. In the following, we will explain how this is possible and how the ACP group will build a supercomputer for high-energy physics at Fermilab.

A High-Energy Physics Supercomputer

"A super computer is a system that is only one generation behind the computing requirements of leading edge efforts in science and engineering." (The quotation is from Neil Lincoln, designer of the CDC Cyber 205 Super Computer.) By this definition, the ACP Multiprocessor system to be built by the end of 1985, is more than a supercomputer. The concepts for this system were developed during 1984. Circuit design is now underway. The design is based on a careful evaluation of the criteria by which the value of such a system to high-energy physics should be judged, as well as what is required to gain acceptance from the physicists who need to use it.

As important as the problems are, there are still obvious limits to the amount of money that can be spent to solve them. It is clear that a very important factor is cost effectiveness: the rate at which computing for a problem can be carried out, divided by the cost of the computer. Digital Equipment Corporation's (DEC) Vax 11/780 is a super-mini computer that is very popular in the scientific community and is a good standard for comparison of cost effectiveness. One can buy about 4 Vaxes per $M (million dollars).

Cost effectiveness is not the sole criterion. It is possible to obtain extraordinary cost effectiveness, approaching a million Vaxes/M$, using special purpose hardware aimed at extremely well-defined problems. Examples may be found in high-energy physics experiment trigger hardware (that decides which interactions detected by an experiment should be recorded on tape) and military signal processors. Such systems are very inflexible and difficult to program. Getting them working makes strong demands on technical people's time.

These problems point to the two other requirements, beyond cost effectiveness, that the ACP makes of its systems. The first is ease of use and programmability. In one phrase, this is what has come to be known as "user friendliness." The second is easy system set-up by non-experts. This requirement encourages a modular system with units, such as circuit board subsystems, built and tested to industry standards. These modules may be based on Fermilab or commercial designs, and should be routinely available from commercial vendors or fabrication houses.

It is easy to sympathize with scientists who resist new programming languages and complicated computer mumbo-jumbo. Learning a whole new language or a complicated set of procedures would be, clearly, an "unfriendly" requirement. Among high-energy physicists, Fortran is the nearly universal programming language. Although there are several more modern languages with strong proponents in the computer science world, asking high-energy physicists to leave Fortran would be much like asking Frenchmen to speak Esperanto. In fact, the analogy is appropriate since Fortran is a "living" computer language continuously being updated with syntax and concepts deriving from computer science work in languages. At the research stage, before the language has had time to adapt, new functional tools can be made available in the form of subroutines. Subroutines are previously prepared sequences of instructions that are convenient for users of a new computer to invoke from their programs.

An important component of user friendliness is what is called the operating system. The operating system manages the user's files of programs and data, runs computing operations on request, provides tools to help find errors in programs, supports text editors, and, if user friendly, generally assists the user in response to only a minimum of simple commands. The Vax VMS operating system has become very popular among high-energy physicists. Other, more portable systems (AT&T's Unix™, in particular) may in time take hold. Until then, VMS will be the system environment, and Fortran the language in which physicists using the ACP's computers will work.

Computer Architectures for High-Energy Physics

The most cost effective commercially available computing engines are the VLSI microprocessors. A single board computer based on one of the newly emerging 32 bit super micros (such as Motorola's 68020, AT&T's 32100, and DEC's microVax chip) will run large Fortran programs at speeds approaching those of a Vax. Critically important to using these tiny computers are the programs, called compilers, that translate the scientists' programming language, Fortran, to the machine instructions that control the microprocessors. Much inefficiency is possible in this translation. A particularly good compiler for the 68020 is now available from Absoft, a small company in Royal Oak, Michigan. The ACP has already measured physics programs to run at upwards of 1/2 Vax speed with it.

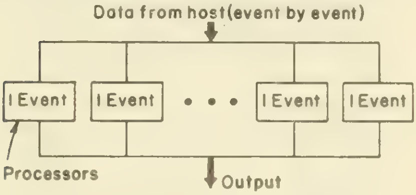
Such a single board computer can be built for about $2500, implying a cost effectiveness of at least 200 Vaxes/M$. Further improvements are expected by 1986 in compiler and hardware technology. Clearly, to bring revolutionary amounts of computing at this cost effectiveness to a computing problem, one must get all the little engines to work together, in parallel, on the problem.

The general problem of parallel computing is a very difficult one. Much computer science effort is directed at optimizing parallel computation for a generalized mix of computer programs. This involves development of mechanisms for communicating between and synchronizing the activities going on in the different little engines. Further complications result from allowing access by each processor into the memory of the others and in the management of the processors and their allocation to different parts of the problem.

Driven by pleasantly easy structures in high-energy physics computing problems, the ACP is able to use the simplest multiprocessor architectures. These involve little or no communication between the processors. Yet, such systems will greatly increase the computing capacity available for this research. In fact, very much can be learned about the general problem of parallel processing from conceptually simple multiprocessors. In time, the simplest architectures can be built up to more complex and general systems.

Why can the ACP avoid the complexities confronting so much other parallel computer research? The secret of how to apply a simple parallel computer to the experimentalist's needle and haystack problem is the haystack itself. It is made of millions of individual events. The reconstruction of what happened in each can be carried out with no regard for what went on in any of the others. Only when the reconstruction of all events is complete do the analyzing physicists want to look at them all together for statistical studies. The problem has designed the computer architecture for us: each of our many little computing engines works, by itself,

on one event at a time, never needing to communicate with the others which are working simultaneously on different events. Raw detector data is passed to each processor as it becomes ready. When the procesor has completed working on the event, the reconstructed physics parameters are stored for the later analysis.



Now, you might think, this is a specially simple architecture. How can it work for any other problem? Physicists are very excited about the studies going on for the Superconducting Super Collider (SSC) which will require accelerator rings about 100 miles around. Projected costs of several billion dollars clearly motivate an intensive computer simulation of accelerator design possibilities. The simulation calculates step by step how individual particles would pass through magnet after magnet, revolution after revolution for thousands of turns around the imagined ring. Many individual particles, starting out with small differences, are followed. The calculation of each track is essentially independent of the others. We can treat each particle like an experiment interaction and put it into its own processor. The processors, once again, need communicate little or nothing with each other.

Both of these important Fermilab problems are, we now see, of an "event-oriented" nature. They are perfectly matched to our simple parallel architecture. We are learning that outside our world, there are many important problems of an event-oriented nature. Some of these are surprising at first glance: process simulation, robotics, animation, and finite element analysis. Of course, we cannot get away with applying our event-oriented architecture to every computing problem. Some, like weather forecasting and molecular dynamics, require heavy communication between all processors. Many others in mathematical physics require only nearest neighbors talk to each other. An example is the key theoretical problem of particle physics.

Theorists have developed a numerical calculational technique, called Lattice Gauge Theory, to make approximate predictions that test the theory of strong interactions. They simulate the world, at the elementary particle level, on a lattice of points in space and time and calculate the interaction of quarks as if they lived on that lattice. These calculations are of the highest importance. To do them with reasonable accuracy, they require orders of magnitude more computing than presently available. A grid of processors each speaking to only a limited group of neighbors matches this problem in an obvious way. The individual processors are just like those the ACP is designing for event-oriented problems. In the future, the ACP may configure systems as grids. However, with work on grids in progress at Cal Tech and Columbia, the group is presently not emphasizing them.

Software

Scientists, like other computer users, are accustomed to preparing programmed instructions for traditional machines that compute by carrying out arithmetic or logic operation serially, one after another. The present generation of commercial supercomputers, like the Cray 1 and Cyber 205, are called vector processors. They are capable of carrying out the same operation, on one command, for each of the set of numbers that make up what is called a vector. In order to take full advantage of this capability for a scientific problem one needs to identify, throughout the problem, groups of calculations that can be ganged together in the vector processor. Automatic tools that "vectorize" a problem have not proven very effective. Doing this job by hand is difficult and time consuming. Rarely have scientific problems used more than 10% on average of a vector computer's capacity. This experience shows how critically important it is to have software support that makes it possible to take full advantage of new hardware.

Truly parallel machines, where different operations may be carried out simultaneously on groups of numbers, are expected to be less constraining. Event-oriented problems like experiment reconstruction should be particularly easy to adapt to the simple parallelism of the

ACP multiprocessor architecture, which is designed for them. During 1984, the ACP built a small six unit testbed multiprocessor and developed an extensive repertoire of software to support use of large multiprocessors by experimentalists. Several Fermilab experimental groups tested this software over the summer months. They found it pleasantly easy and quick to convert their traditionally serial programs to multiprocessor operation.

A program that is to run on the ACP multiprocessor is separated into two major pieces. The first runs on a single processor, called the host. It contains all instructions that control bringing in raw data from, and sending processed results to, outside storage devices, such as magnetic tape. The real number crunching is carried on in the second piece of the program. This is duplicated many times over to control the activities of each of the many little microprocessors that together do the heavy work. The host computer is instructed to send the raw data corresponding to one physics interaction event "down" to a processor by a simple request to start a sequence of instructions, a subroutine, previously prepared by the ACP.

The name of this subroutine is obvious, SENDEVENT. There is a similarly obvious name, GETEVENT, for the subroutine that retrieves processed results from a finished microprocessor. What is not obvious is the "resource management" problem of keeping track of which of over a hundred processors is ready for data, ready for retrieval, or requires some other action. These matters are handled automatically by ACP subroutines. The scientist using the system does not have to bother with them. He or she is required only to determine how to split the program into the host part and the microprocessor part and to identify appropriate places to insert the SENDEVENT and GETEVENT commands that communicate data between the host computer and the little number cruncher. This is an easy task since all large reconstruction programs have separate input-output and number-crunching sections.

The host computer also takes care of tasks needed to start up and complete a reconstruction program's operation. At the beginning, many numbers that describe where the detectors are located, and otherwise give meaning to the raw readings, must be prepared. These numbers are then broadcast to all the processors, where they will be used to reconstruct the event, with the command BROADCAST. At the end, statistical summaries and graphs are normally prepared so that physicists can determine that the operation proceeded normally. These summaries are based on subtotals stored in the many individual processors. The subtotals are gathered and summed together on command to the ACP software. There is also help when problems occur. Hardware and software errors are identified and tools provided to track down program mistakes.

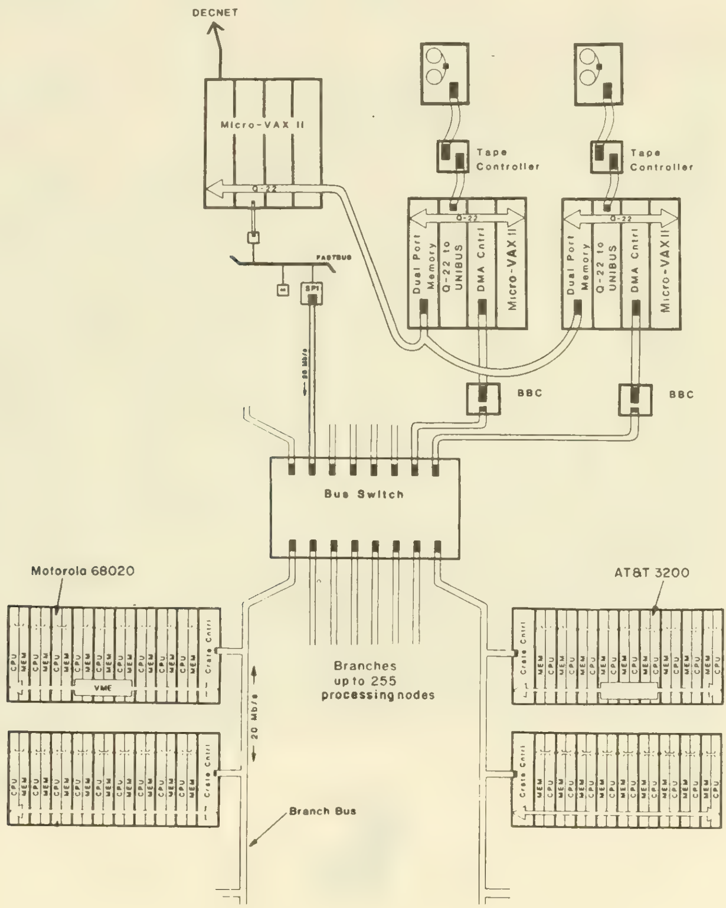
Hardware

The tests of the ACP software demonstrated that it will be easy to apply a simple multi-microprocessor to high-energy experiment computing. The enthusiasm of computer-starved experimentalists has put a high priority on a project to build a full-scale, high-performance system before the end of 1985. It will consist of 128 processors. Of these, 64 will be based on Motorola's 68020, and the remainder, depending on availability, on AT&T's or DEC's 32-bit microprocessors. Using more than one processor type is part of the ACP's philosophy of keeping its system receptive to the best industry has to offer in performance and in price.

Experience with this first system, running real experiment problems, will allow ACP people to improve software and hardware. If, as expected, all goes well, other large systems, of up to 255 processors each, will be built quickly to meet the needs of Fermilab's Computer Department and the Collider Detector at Fermilab (CDF). Many outside groups, at American and Western European universities and laboratories, have followed ACP activities with interest. To make duplicating the system easy, Fermilab will make available system designs, software, and lists of commercial sources where modules may be purchased.

Even though the architecture is simple, putting together this large a multiprocessor requires careful design. Up to 20 processors can be assembled in a box, called a "crate," using commercial packaging and interconnection circuits. For larger numbers of processors, new schemes are required. The ACP multiprocessor will be built as a tree (which is usually pictured

upside down in diagrams). The leaves are the individual processors sitting in a commercial crate. The crates are connected in groups to a Fermilab designed "branch bus" which in turn can be connected as needed to any of the one or more roots of the system. Each root is connected to a source of data from the outside world. In some systems, there will be two roots each with a magnetic tape drive, one with raw data coming in, one with processed data going out. Other systems will process data as quickly as it is taken in the real time of an experiment. There, roots will be connected directly to the experiment's data acquisition system absorbing data at huge rates. Twenty million characters per second are possible in each of several roots. A simple, but high speed switch is the trunk of the system. It connects 8 roots to 8 branches.



Each root is controlled by a small commercial microcomputer (DEC's microVAX II). These speak with a DEC microVax II supermicrocomputer which is the boss of the system as a whole and is called the production host. This computer carries out the host part of the experimentalist's program and has the popular VMS operating system we referred to earlier. One experiment's activity at a time goes on in the production host and multiprocessor, which is connected to Fermilab's network of computers. Also on this network is a "development host" computer, a full size Vax that can handle many people each working on developing new programs. They can test the programs on small ACP systems intended for this purpose and connected to the network. The development host has available all the ACP supplied tools, as well as the usual Vax VMS aids to development, that help prepare for a multiprocessor calculation.

The first system will be built in 1985 for under $1/2 million in equipment costs and will deliver the computing power of at least 60 Vaxes. Later copies will be cheaper and more powerful. The ACP schedule is "aggressive," to use a popular computer industry word, because it depends on the ability of industry to manufacture, in quantity, 32 bit microprocessors. These devices are certainly among the most technologically aggressive creations ever contemplated. However, delays, if they occur, will not be long, and are part of the ACP's mandate to work on the cutting edge of technology.

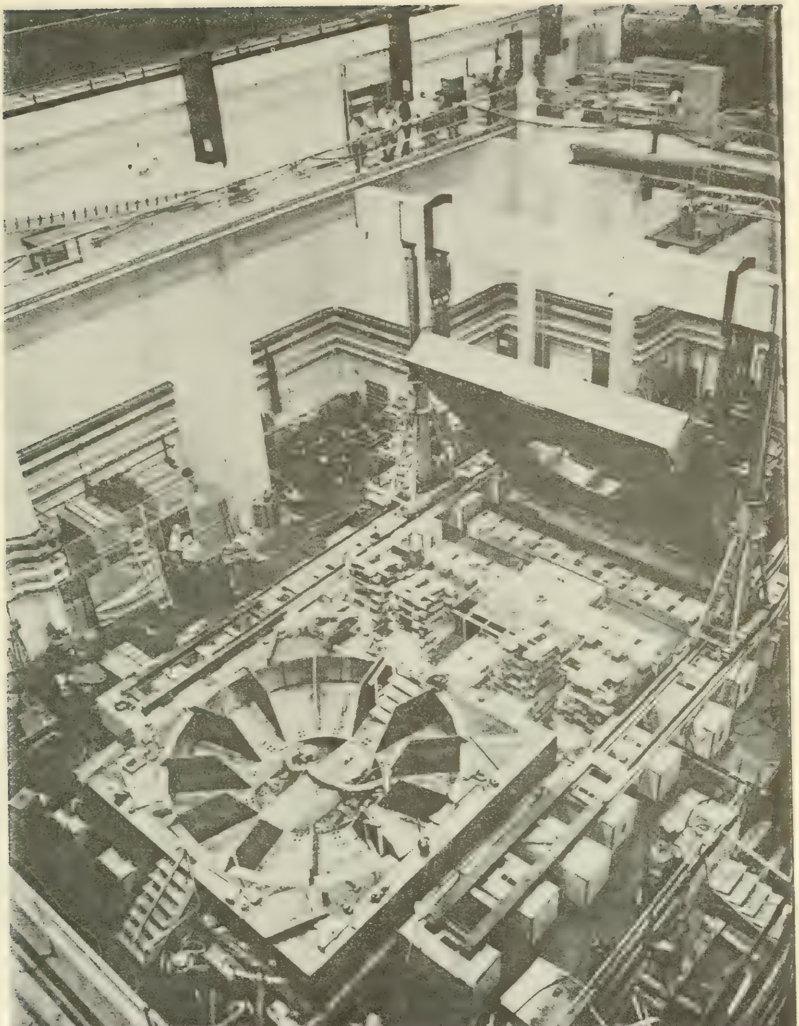
Future Activities and Projects

We have hinted at areas where further ACP development work potentially could make still more dramatic improvements in productivity. One such area of research is on special-purpose devices. We said these are hard to program. But suppose that ACP experts do the difficult work as they have done for multiprocessor management software. Then these super powerful techniques could be made available to physicists with only a subroutine command. This concept, which we call "hardware subroutines," appears to be very promising. It is particularly easy to implement when one can identify time consuming little calculations that are repeated over and over again. This appears to be possible for all the problems that interest us. Since the approach can be so fruitful, the ACP group will focus on it in 1986.

Number crunching is the major source of long delays in physics turn-around times. Another leading contribution is simply the time necessary to plow through huge amounts of processed data. Reconstruction of an experiment produces tens of billions of words. These are used by physicists to make graphs and statistical calculations that describe what went on in the experiment. Little actual computation is required for this analysis. Yet, each time a physicist passes through this enormous amount of data, hundreds (or even thousands) of tapes must be read, and often several days are lost. Typically, an experiment requires many such passes as physicists try out new ideas and develop an understanding of the data.

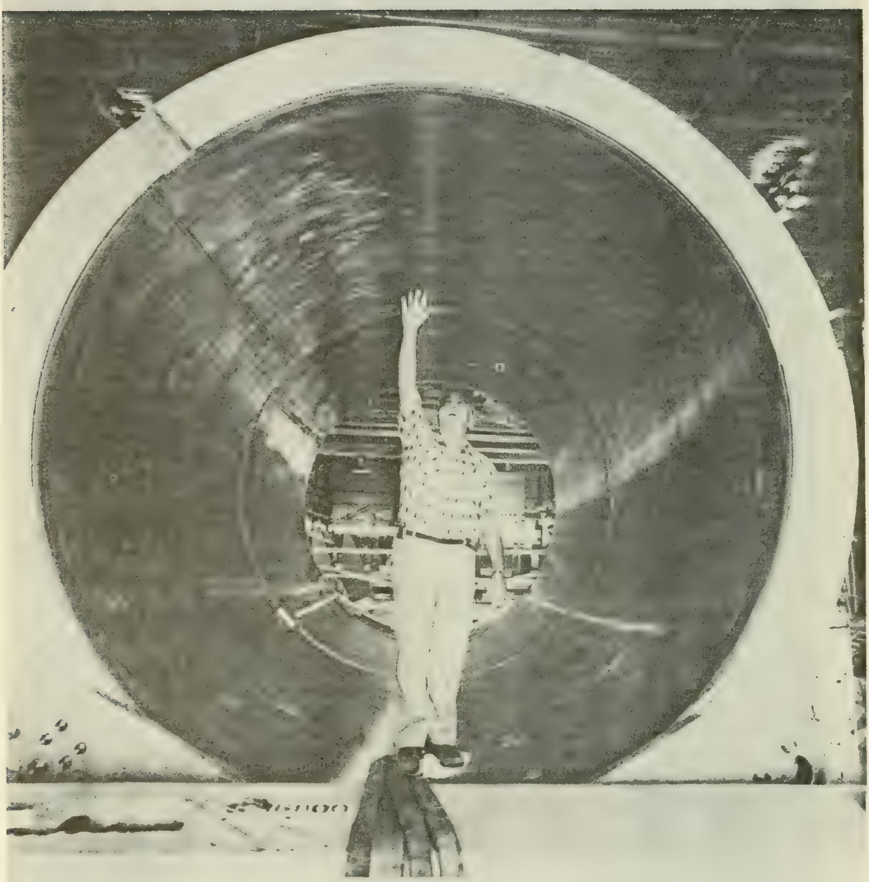
New data base technology (similar to that used for TV laser disks) is appearing on the technological horizon that will make it possible to improve this situation. Using the new technology, future ACP efforts will be directed at allowing physicists to turn around their analysis ideas almost as fast as they can think of them. For now this is a dream, and Fermilab's Advanced Computer Program is fully occupied developing its exciting new supercomputer for high-energy physics.

Thomas Nash



V. Progress on the Fermilab Collider Detector

The south end wall of the Collider Detector under construction as the north end wall is raised into final position.



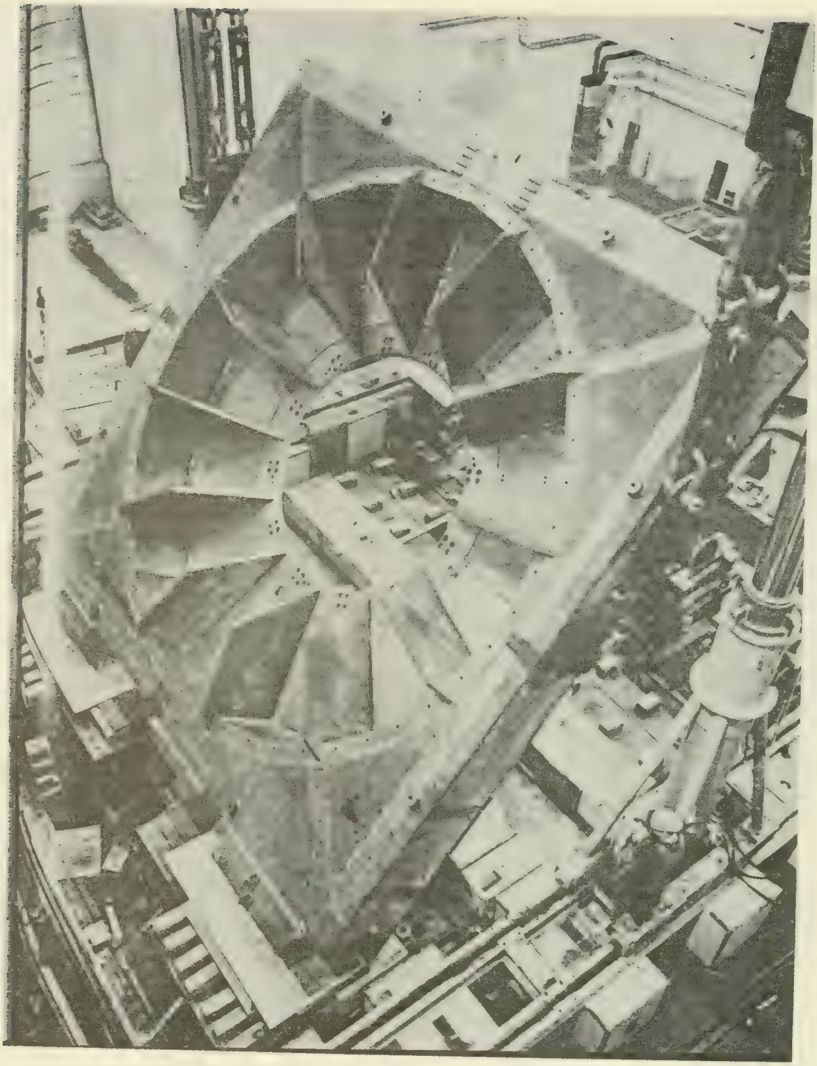
Pete Lentini measures up against the superconducting solenoid coil.

←

The solenoid coil arrives at O'Hare International Airport from Japan.

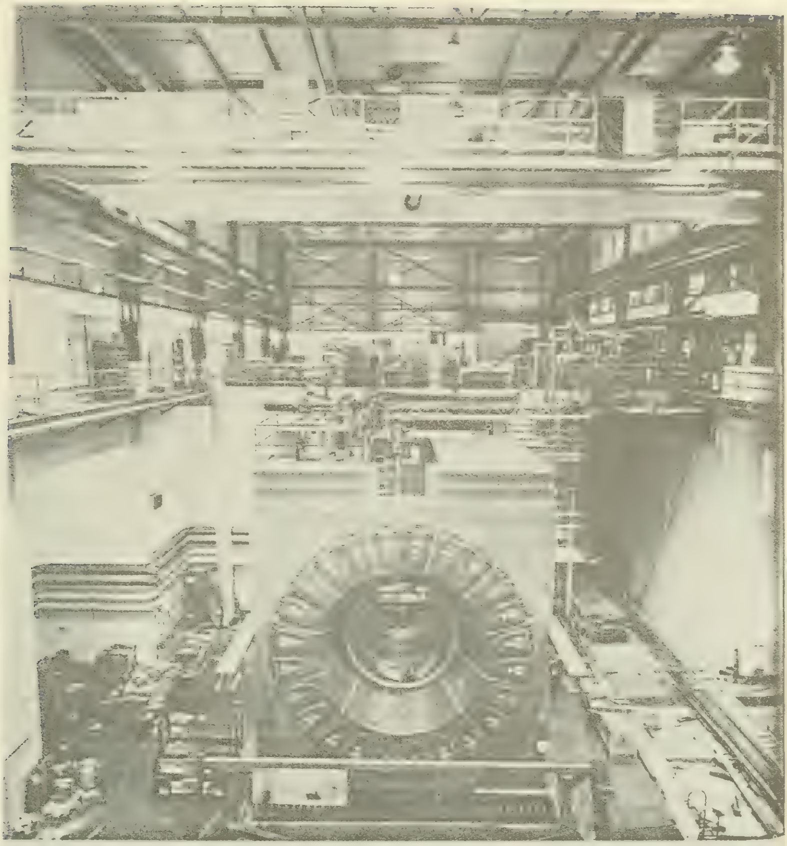
Welding the support ribs on the magnet end wall.

Raising the north end wall of the solenoid magnet yoke.

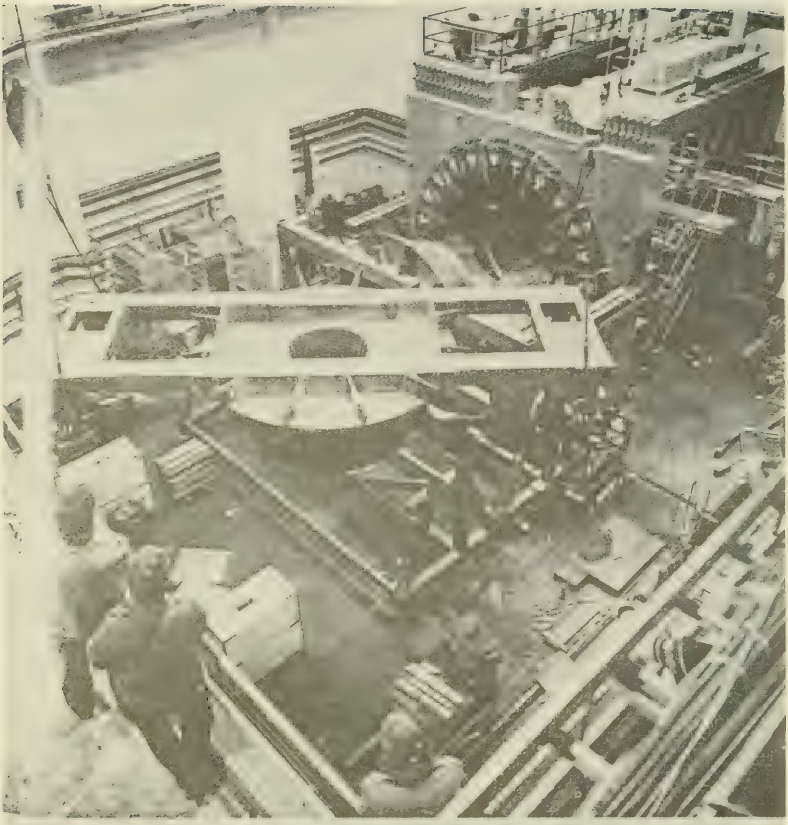


Preparations for the installation of the final-focus magnets (low-β quadrupoles).

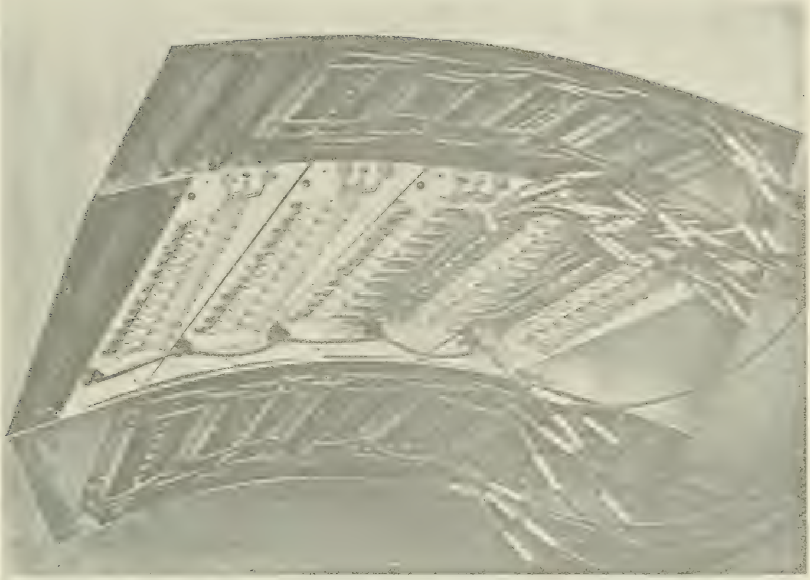
Installation of the low-β quadrupoles into the Tevatron at BO.



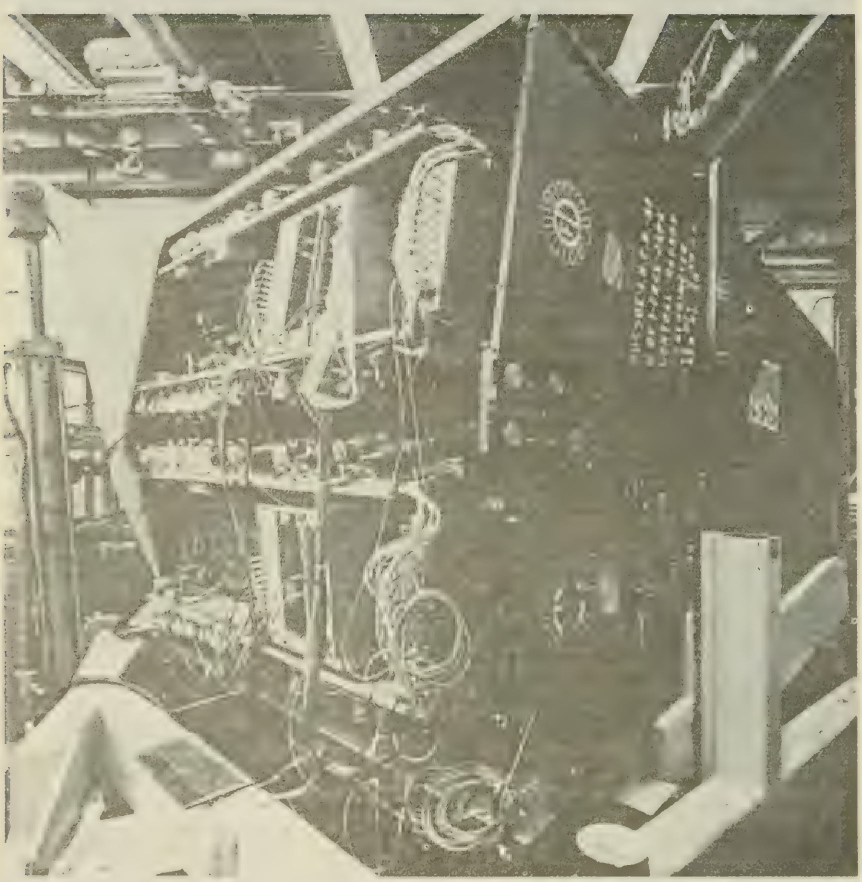
The completed magnet yoke with the solenoid coil, cryogenics, and end-wall calorimeter modules installed.



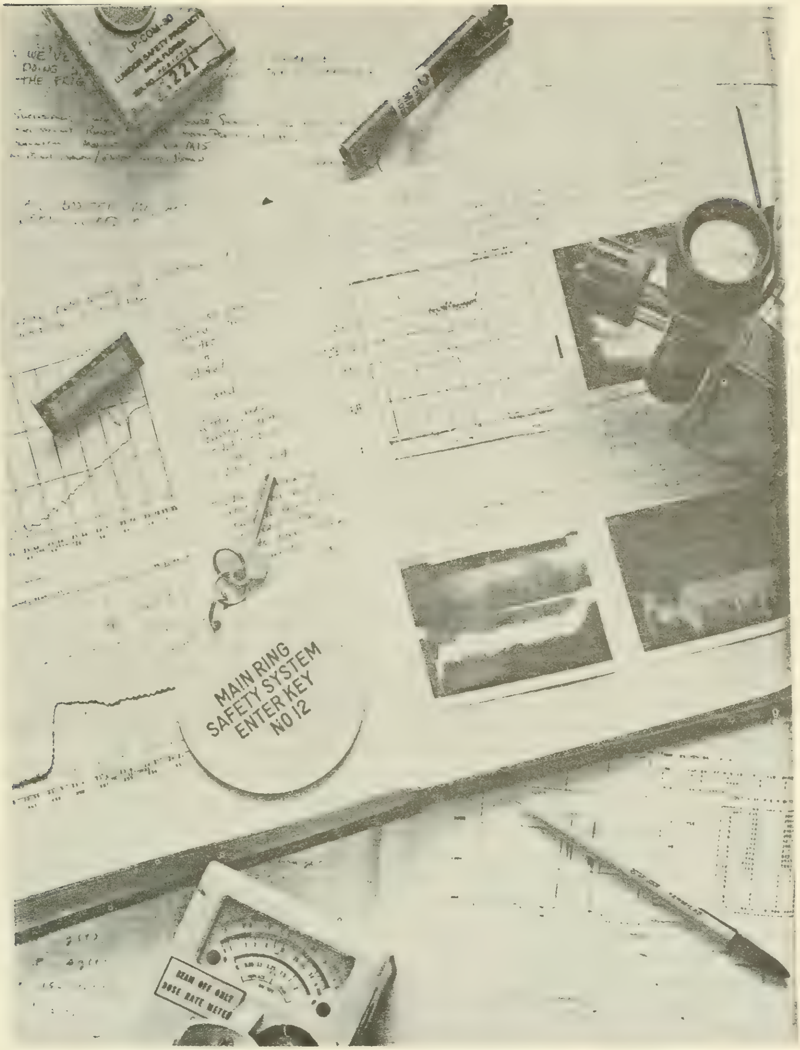
Lowering the second magnet end plug into the Assembly Building pit.



Prototype of the central tracking chamber preamplifiers and special wire alignment blocks.



Completed central calorimeter modules undergoing final testing and calibration in the NW beam line.


MAIN RING
SAFETY SYSTEM
ENTER KEY
NO 12
DOSE RATE METER

VI. Development of the Energy Saver Operation.

Introduction

The completion of the Energy Saver commissioning, described in detail in last year's Annual Report, is only the beginning of the Laboratory's mission. Only when protons of appropriate intensity are being delivered to the targets in the Meson, Neutrino, and Proton Laboratories, with the uniform spill the various experiments require and for a reasonable number of hours per week, will we be able to consider our task successfully completed.

The primary objective in 1984 was, in fact, to establish again at Fermilab a valid high-energy physics experimental program, first at 400 GeV and then at 800 GeV. Preparations for the startup of colliding beams in 1985 also continued. This section presents the accelerator story, including the successes, failures, and activities during the '84 summer and fall shutdown, which should lead to substantial improvements in 1985 for the fixed-target program and allow proton-antiproton collisions in the Tevatron when the Antiproton Source commissioning is complete.

The Tevatron

This new accelerator was called the Energy Doubler (because it gives twice the proton energy of the original Fermilab Main Ring), the Energy Saver (because superconducting magnets and the necessary refrigeration use less energy than conventional copper-iron magnets), and it is now the Tevatron since one-trillion electron-volt energies are achieved. The performance specifications given for the Tevatron before its construction were that it should provide proton beams of energy 800 GeV to 1 TeV with an intensity of at least 2×10^{13} protons per pulse. The cycle time was to be 30 to 60 seconds, with a flattop of at least 10 seconds.

In the first full year of operation, most of these specifications have been met. The Tevatron has operated regularly at 800 GeV. The intensity is greater than 10^{13} protons per pulse and is not limited by the Tevatron, but by its injector. A cycle time of 60 seconds is standard; shorter times can be achieved when more rf is available. A flattop of 10 seconds was used during the first running period; 20 seconds is now standard.

Chronology of the Year

We have had a successful year in the sense that we met or almost met all performance specifications. We have worked hard to meet our operating schedules and here our success has not been as comprehensive. Let us step back a bit from the official start of the year 1984 for a running start, or a starting run.

High-energy physics experiments at 400 GeV with the Tevatron began October 3, 1983. By November 1, beam was delivered to the Meson Lab and experiments began taking data. A little later, on November 21, beam was delivered to the Neutrino Lab and soon seven target stations were in use, a solid experimental program.

The 400-GeV warmup run continued until February 14, when the accelerator was shut down on purpose. The main purpose of the shutdown was for installation of new equipment, but before that, operation at 800 GeV was tried. The tests were successful, accelerating beam to 800 GeV and storing it at that energy.

The Tevatron was shut down until March 17 for installation of the low-beta quadrupole system at B0. The purpose of this system is to reduce beam size and therefore to increase beam density at the interaction point. This will increase the luminosity of proton-antiproton colliding beams.

The obligatory odious ordeal of startup began on March 17, and the beam was ready for the first 800-GeV high-energy physics run on March 25. It was, however, a short interlude, because the first failure of a Tevatron magnet occurred the next day.

Replacing a superconducting magnet is much more lengthy than replacing a Main-Ring magnet because a portion of the ring (1/24, corresponding to one satellite refrigerator's worth of

magnets) must be warmed up to room temperature, then cooled again after the magnet is replaced. The 800-GeV run was restarted on April 1 and went on from there.

There was an interruption of high-energy physics on April 18 for testing of the low-beta quadrupole system at location B0. The tests were very successful; it was possible to start with the low-beta system turned off, as will always be the case during acceleration. Turning the system on changes the operating characteristics of the beam already in the accelerator.

The only other scheduled interruptions of high-energy physics were for routine maintenance and briefly for the dedication of the accelerator on April 28. The run continued until July 16, but there were four more magnet failures in June and July. We discuss these failures in the following section.

The accelerator shutdown that started July 17 was a long one. The tunnel was excavated at F17, and a number of the precast tunnel hoops were replaced by ones of larger cross section to allow more room for equipment for extraction of beam to the antiproton-production target, and for reinjection of antiprotons. In addition, the tunnel was modified at D0, the second colliding-beams interaction region, for installation of the components for the overpass that locally raises the Main-Ring beam by approximately 6 feet to leave room for a detector. During this long shutdown, the ring was warmed up and modifications made to correct the problems causing magnet failures.

Startup began on November 3. There was a certain amount of discreet nail biting. Components for the D0 overpass were delivered from the Magnet Factory at the last moment, and there was some worry about whether the whole installation would work. Purposely taking the beam away from the plane of the accelerator was a brand new adventure. In fact, it worked very well after only a few days of commissioning. Beam was accelerated in the Main Ring and injected into the Tevatron on December 2. Tests continued through December, with the second 800-GeV high-energy physics run to begin on January 3, 1985.

Performance

The best way to talk about performance is in terms of the scheduled and actual hours and the number of protons on target. We give these data in the accompanying table.

Table I. 1984 Accelerator Performance.

	400 GeV	800 GeV	Total
Number of Weeks	18	10	28
Scheduled HEP Hrs.	2042	1276	3318
Actual HEP Hrs.	1131	648	1780
% Up Time for HEP	55	51	54
Weekly Averages			
Scheduled HEP Hrs./Week	113	128	
Actual HEP Hrs./Week	63	65	
Accelerated Protons			
Protons/10^3 Scheduled Hrs.	$2.7\text{x}10^{17}$	$1.3\text{x}10^{17}$	
Protons/10^3 Scheduled Hrs., Best Week	$5.5\text{x}10^{17}$	$2.5\text{x}10^{17}$	

In interpreting the data from the above table it is important to note that even in its initial running period from October 3, 1983, to February 14, 1984, problems with the Tevatron prevented running only about half of the scheduled time. For the best week $5.5\text{x}10^{17}$ protons/10^3 scheduled hours were accelerated, with the average for the 18 weeks of 400-GeV operation being $2.7\text{x}10^{17}$ protons/10^3 scheduled hours. The fraction of running time is at least as good and the intensity much higher than in the first year of Main-Ring operation.

The level of operation at 800-GeV is not typical of what we expect in the future because of the five Tevatron dipole magnet failures. These failures were due to an unsupported section of superconducting cable. Immediately after leaving the coil package, the cable is bent upward through 90° and held by an insulating block-clamp. The cable then is bent through a semicircle, at the end of which is another insulating block-clamp that directs the cable to the next magnet through the helium connection. Five magnet failures during the 800-GeV run were attributed to the 6 inches of unsupported cable between the two insulating blocks. When the magnets are ramped from injection

field (150 GeV) to 800 GeV, the cable experiences a force of approximately 100 pounds which causes the cable to move and rub against cryostat parts, resulting in abraded cable insulation, a short-to-ground, and, ultimately, magnet failure. The cables at the other end of these magnets have proper support. Whenever this happened the magnet had to be replaced. In order to remove and replace each damaged magnet it was necessary to warm up 1/24 of the ring. After replacing each failed dipole, cooldown and refilling with liquid helium required approximately two days. Three to four days were lost for each magnet failure.

This major problem has been eliminated. Because of the already scheduled shutdown of the Tevatron from July to November 1984, it was possible to open the 380 magnets that needed to be modified. After grinding away approximately 10 inches of weld on the cryostats, a cable support was incorporated that was known to be adequate to prevent conductor motion. This work has been done and the Tevatron has been successfully ramped to 800 GeV (November 29, 1984) with the repaired magnets.

The Tevatron was also used for SSC studies. Even though these efforts have been kept at lower priority than the Fermilab experimental program, some interesting observations were possible which may influence the design of the SSC. Beam measurements made on the Tevatron were compared with computer simulations, showing a high level of predictability. Coasting-beam studies show long lifetimes and lack of strong resonance driving terms. Low-energy studies were made to demonstrate that injection energies of as low as 1/15 of final energy are possible.

Other Activities

In addition to providing support that made possible the work described above, the various accelerator departments participated in other activities during 1984. Several examples are given below by Curtis Owen, Injector Department Head; Gerald Tool, Electrical Engineering Support Group Leader; and Dixon Bogert, Accelerator Division Controls Group Leader:

Curtis Owen: Injector

Vacuum tube circuits in the anode modulator for the Linac final power amplifiers and in the screen modulator for the driver amplifier were replaced with much simpler and more reliable solid-state devices. After several months of prototype development, the conversion was accomplished very smoothly during the long 1984 shutdown. A second project was the design and installation of an additional 8-GeV extraction system for the Booster. The primary reason for this is to provide an 8-GeV test beam for the Debuncher Ring (TeV I); however, the extra extraction system and beam dump will be invaluable in the course of normal operation with the Main Ring and Tevatron. It will permit Booster beam studies and tuning at a reasonable rate parasitically without dumping 8-GeV beam in the Main Ring or in the Booster. The design allows an arbitrary fraction of the 84 bunches of beam in the Booster to be delivered to the Main Ring (for bunch coalescing studies or any other purpose) with the remainder delivered to the new beam dump.

Gerald Tool: Electrical Engineering Support

A program was carried out to rebuild the A2 and A3 Tevatron power supplies to provide steady-state operation of the Tevatron at energies up to 1 TeV for colliding beams. At any given time, one of these is the holding power supply, and the other is an installed spare operating as one of the 12 ramping supplies. This group, as well as

other Accelerator Division support groups, made significant contributions to designing and implementing antiproton source systems. It is estimated that during 1984 about 80% of this group effort involved TeV I work.

Dixon Bogert: Accelerator Division Controls

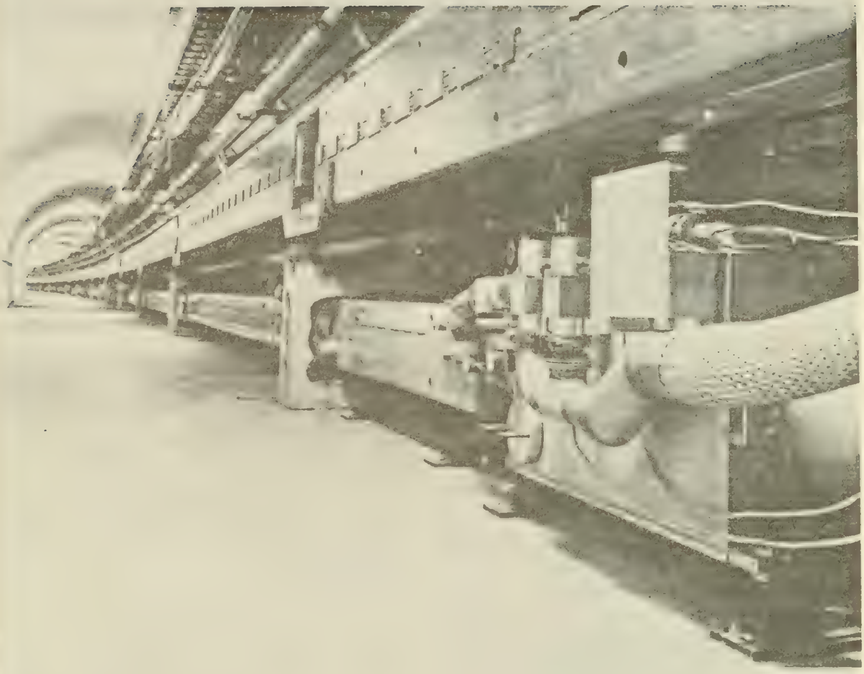
Major tasks undertaken were: 1) Conversion of the Main-Ring Control system to the ACNET system, culminating in the successful operation of the Main-Ring including the D0-overpass in November 1984; 2) Ongoing development of the controls required for the $\bar{p}$ source; 3) Continuing support for the improved operation of the Tevatron including new items such as the B0 low-beta region, the QXR system (quadrupole extraction system), and super-damper control with the possibility of tune measurements of the Saver made at 50 Hz; 4) The continued improvement of general ACNET services including alarms and Save-Compare-Restore capabilities; 5) The acquisition, in conjunction with the AD/Calculations Group, of a third VAX 11/785 computer and a Floating Point Systems FPS-164 attached processor. This equipment will greatly improve the Accelerator Division's ability to study and simulate accelerator performance and future accelerator designs. There were 62 man-years of effort recorded by AD/Controls during 1984. Nineteen of these years, or about 30% of the total, were devoted to support for the $\bar{p}$ source. The greatest part of this support was electronic development of control modules and systems, including microcomputer support. Nine man-years of effort, or about 15% of the total, were devoted to ongoing support for the Tevatron systems as outlined in number 3) above. The remaining 55% of the effort was devoted to a combination of conventional controls support and the Main-Ring Conversion project. The ACNET control system now has 14 consoles operational. With the exception of the Booster, all components of the accelerator are now controlled through ACNET.

Support for the $\bar{p}$ source controls has included several new micro-computer projects. The decisions made several years ago to support the $\bar{p}$ source as an extension of the ACNET/Tevatron controls system has greatly simplified the job of creating software interfaces for TeV I.

Conclusion

In summary, the first two high-energy physics runs, October 1983 to February 1984 at 400 GeV, and March 1984 to July 1984 at 800 GeV, were highly successful. Accelerators using superconducting magnets have come of age and future accelerators such as the proposed SSC can now, with confidence, move forward using the Tevatron as a solid technology base.

William B. Fowler



VII. Magnet Production at Fermilab

Introduction

Almost all of the work of Fermi National Accelerator Laboratory involves the use of electromagnets in one way or another. From its very beginning, the Laboratory has been involved in purchasing magnets, building magnets, modifying magnets, repairing magnets, or advising others on the subject of magnets. With the completion of magnet production for TeV I and TeV II, well over 3000 major electromagnets have been assembled at Fermilab for use in both accelerator construction and experimental programs. If smaller magnets ("trim" magnets for orbit correction or beam steering) are included the total number rises to 4-5000.

At different times, and in different places, magnet design and construction have gone forward under organizational names as diverse as: The Magnet Factory, Technical Services, Technical Support Section, Industrial Area, and Energy Doubler Magnet Group.

Whatever the designation or place, the central role of magnets in Fermilab's evolution has remained unchanged. The following review of this crucial activity provides a glimpse into some of the Laboratory's history.

Conventional Magnets

In the late 1960s-early 1970s, activity at what was then known as the National Accelerator Laboratory centered around planning the design and fabrication of magnets for the Main Ring, the 200-400 GeV conventional accelerator. Finding the answers to questions regarding design, external procurement of components, on-site versus off-site fabrication, assembly and measurement, and eventual rework of magnets as design modifications became necessary, led members of the design group through a chain of decisions that would prove useful in later years.

This was a large and revolutionary undertaking: the construction of upwards of 1000 magnets in the relatively short time frame set by Robert Wilson's desire to have an operating accelerator on time and under budget.

The process of 400-GeV magnet fabrication began with planning and design at an Oakbrook office complex, moved into early testing at Argonne National Laboratory, then to preliminary fabrication in rented warehouse space in West Chicago, and in the Village on the NAL site. The need for very precise alignment of the inner coils close to the median plane, and the reluctance of industry to try to meet this tight specification led the Laboratory to build the coils in-house. By 1970, decisions on fabrication and assembly had created the need for an industrial complex at Fermilab. Industrial Buildings 1 and 2 were constructed and occupied as a test facility, and coil-winding and assembly facility respectively.

As completed magnets were placed in the Main Ring, where they were subjected to actual operational loads, production-related electrical problems arose that occupied the Magnet Facility for nearly a year before the actual business of operating the accelerator could proceed.

With the completion of the 400-GeV accelerator, efforts in the Magnet Facility turned to supplying the magnets needed in the Experimental Areas. A proliferation of magnet types and variances were required, from analyzing magnets to bending magnets, from septum magnets to EPB dipoles. Since flexibility now assumed pre-eminence over quantity, the Magnet Facility underwent a transition from the mass-production techniques used on Main Ring magnets to the smaller-scale production better suited to specialized production.

The Saver Era

By 1975, planning for the Energy Doubler (later the Energy Saver, and then the Tevatron) had been approved, and serious development effort had begun on a new generation of magnet, the superconducting quadrupoles and dipoles that would be used in the existing Main Ring tunnel to raise the circulating proton energy toward 1000 GeV.

When, in mid-1979, the Department of Energy authorized construction of the Energy Doubler/Saver, a second major production phase commenced, one that repeated the production techniques and demands from 400-GeV days, but that promised an eventual yield of more than twice the energy.

The basic manufacturing philosophy adopted was that, while superconducting magnets could be readily built by highly trained personnel lavishing great care on each magnet on a one-at-a-time basis, production of 1000+ magnets on a tight schedule would not allow for such luxury. Therefore, an early decision was made to develop, once again, new tooling and fabrication techniques that would allow production of superconducting magnets by less-skilled persons at an increased rate of speed, as had been done with the magnets for the conventional Main Ring.

From mid-1979 until early 1983, production of superconducting magnet components spread throughout almost the entire Laboratory. Model cryostats were fabricated by personnel from various Magnet Facility shops in the Village, and final cryostat assembly was carried out in Lab 5 in the Village. Industrial Building 3, constructed and occupied in 1974 as warehousing and storage space, became the production center for superconducting magnets. Room was made available at Industrial 1 for a test facility that included a 1500-watt refrigerator, new water system, upgraded power supplies, state-of-the-art data-acquisition systems and six large test stands for full-scale magnet measurement. By 1978, the demands of completing the Energy Doubler/Saver made clear the need for a fourth building, and Industrial 4 soon was ready for occupancy. Here, completed components for superconducting magnets were tested and stored before final assembly.

Superconducting magnet production hit full stride by 1980, and by 1981 production had risen from 5 magnets per week to 10. By 1982, as many as 20 dipoles were completed in weeks of peak activity. Quadrupole magnets were regularly produced at a rate consistent with their need.

All through the Saver years, Magnet Facility people continued to work on specialized magnets for specific beam lines and experiments. Late in the Saver production sequence, the Magnet Facility was called upon to assemble coils for a very large (60 feet long, with an aperture measuring 4 feet × 4 feet) analyzing magnet for E-605. These coils were formed as two-layer "pancakes" by an industrial vendor, and these "pancakes" were then insulated, assembled, and welded together as single units in Industrial 4. This entire process was carried out in time to vacate Industrial 4 in advance of the onslaught of completed Saver magnets, which eventually claimed all available floor space.

By 1983, nearly 2000 individual components had been completed, assembled, and installed to comprise the Energy Doubler/Saver. In August, 1983, in the spotlight of publicity created by the simultaneous occurence of the International Accelerator Conference at Fermilab, the Energy Doubler/Saver was successfully turned on and commissioned, achieving a new record energy of 800 GeV.

Tev I/Tev II

One might have expected a respite following the commissioning of the Saver. But, as we have noted, activities in other areas of magnet production had carried on right through the Saver era, and were to escalate in the following years.

As a companion piece to completion of the Energy Saver, an antiproton source was required to produce copious quantities of antiprotons that could be re-injected into the Saver and brought into collision with protons to achieve 2 TeV in the center-of-mass physics.

In February of 1981, funding for this antiproton source, or TeV I as the project was to be called, became available from the Department of Energy. A second program, TeV II, was funded in January of 1982. The purpose of Tev II was the upgrading of experimental areas to prepare them for 1000-GeV beam from the new superconducting synchrotron. Taken together, TeV I and TeV II resulted in large demands for additional magnets to be provided by the Magnet Facility, and took Fermilab magnet construction into two years of the most intense effort yet expended.

The Tev I program proved to be the larger of the two, since the number of different magnet characteristics within the program was greater than that of any previous Fermilab magnet pro-

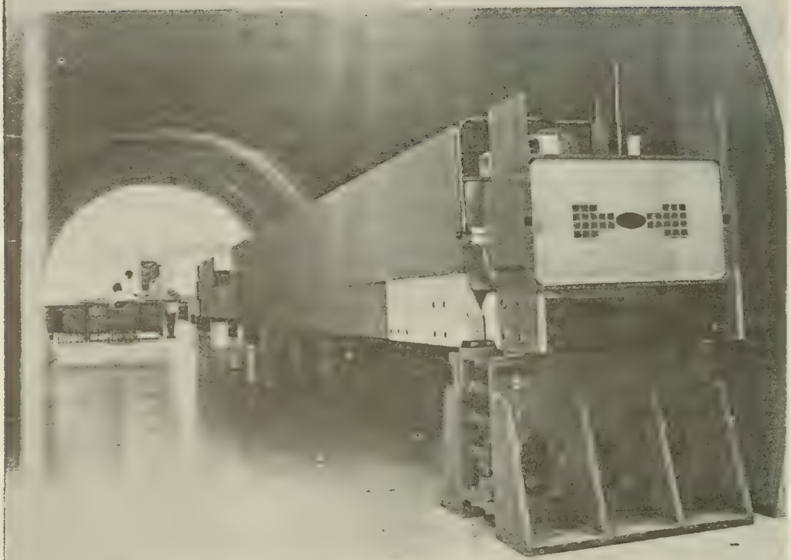
duction sequence. A total of more than 700 magnets consisting of 52 different types, many of which were to push conventional magnet technology to the very edge of feasibility, were called for in the TeV I program, including the largest bending magnets ever built at Fermilab (Accumulator dipoles, each of which weigh 53 tons), and the largest quadrupoles yet constructed at Fermilab. Each of these magnets required a prototyping stage in which production procedures were developed to achieve the required magnetic-field tolerances, low power consumption, and the ability to be taken apart, moved, and reassembled in a reproducible way. From final design through prototyping, production, and testing, the Magnet Facility utilized equipment and manpower to the fullest with around-the-clock and weekend shifts from 1983 through early 1985.

Fortunately, the magnets for TeV II were tried-and-true standbys: 4Q120 quadrupoles, 6-3-120 dipoles, 3Q120 quadrupoles, and special-function magnets for beam-extraction and beam-line use. All in all, it was necessary to build something over 200 additional magnets to meet TeV II needs. Wherever possible, coils and other sub-assemblies were ordered from outside vendors and assembled at the Laboratory in their final configuration.

To assist in this task, the Conventional Magnet Facility, the Energy Doubler Magnet Construction Group, the Central Machine Shop, and elements of Drafting and Design were combined in mid-1981 into one unit, the Technical Support Services Section. TeV I/TeV II production demands were such that a fifth building, Industrial Center, with a different architectural style and substantially greater floor space than the other four buildings, was designed and begun in late 1981. A very rapid construction period resulted in Industrial Center being ready for occupancy and use in little less than a year. Machinery utilized in the construction of TeV I magnets was brought to Industrial Center in late 1982. Existing production equipment was supplemented with help from DIPEC, a stockpile of machine tools maintained by the Government. Principally, 4 large coil-winders were built. The hearts of these machines were constructed from boring-mill turntables left over from Korean War-era tank turret production. Along with these winding tables, large hot-air curing ovens and additional sand-blasting equipment were installed, as well as innumerable small fixtures and peripheral production aids.

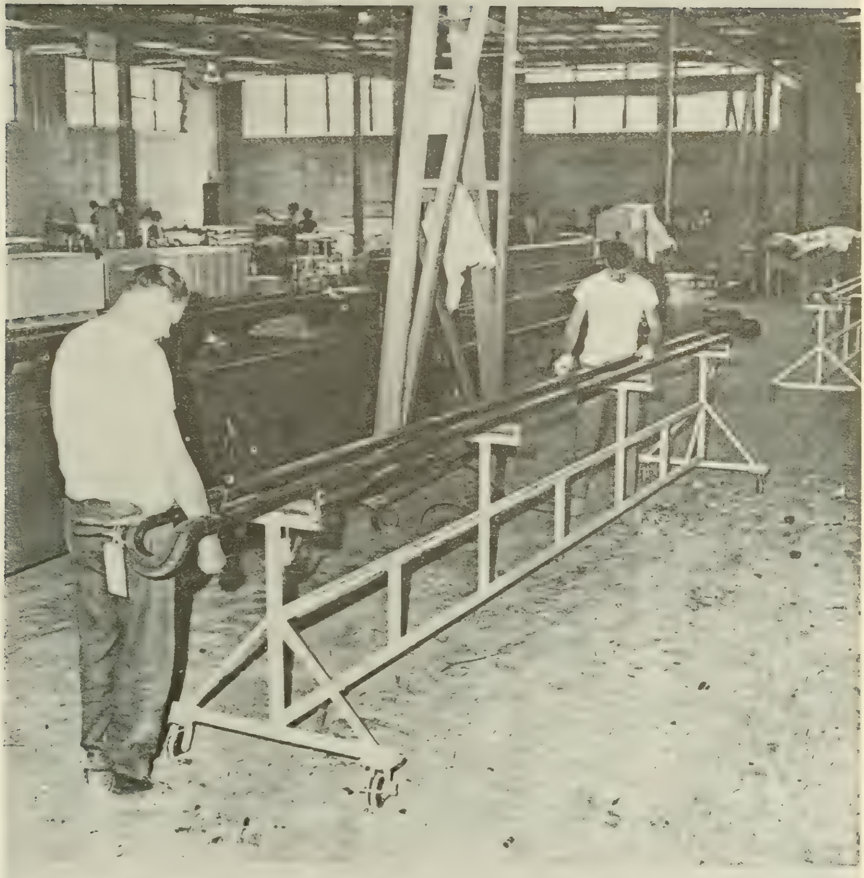
As magnet production for TeV I and TeV II draws to a close, the magnet builders at Fermilab see ahead of them yet another period of development work on superconducting magnets, but this time on a much grander scale: the 20 TeV collider, or SSC, which would operate at 40 TeV in the center-of-mass. These magnets would be made of superior superconductor, and would be 40 to 60 feet long. Some 100 or so of these giant magnets would have to be built and thoroughly tested to insure the success of SSC.

R A Carrigan
Philip V Livdahl

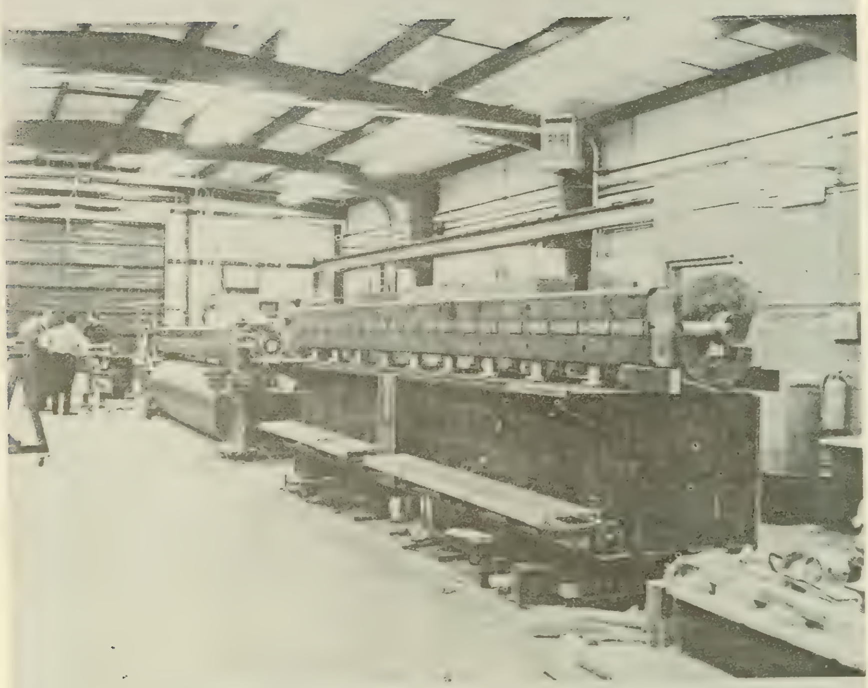


The mockup of an early Main-Ring dipole magnet at the Oakbrook office complex.

Robert Wilson with a model of an early Main-Ring dipole at the Oakbrook office complex in 1967.

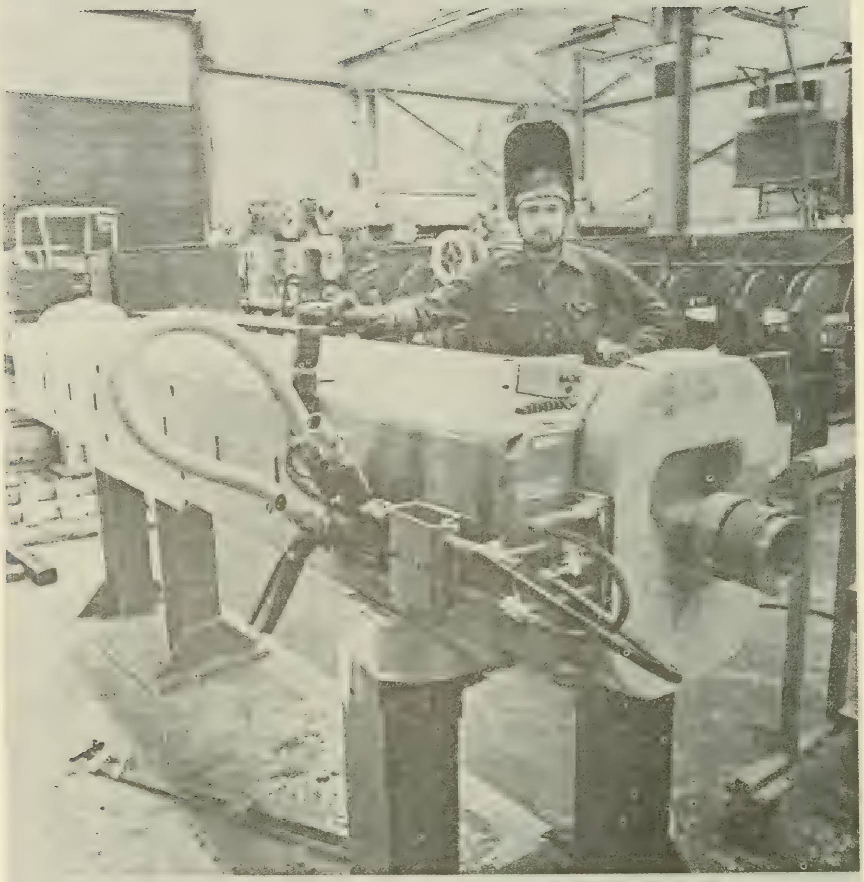


Insulating a coil for a conventional Main-Ring magnet at the West Chicago warehouse, 1970.



A Main-Ring dipole on the granite surface plate in Lab 5.

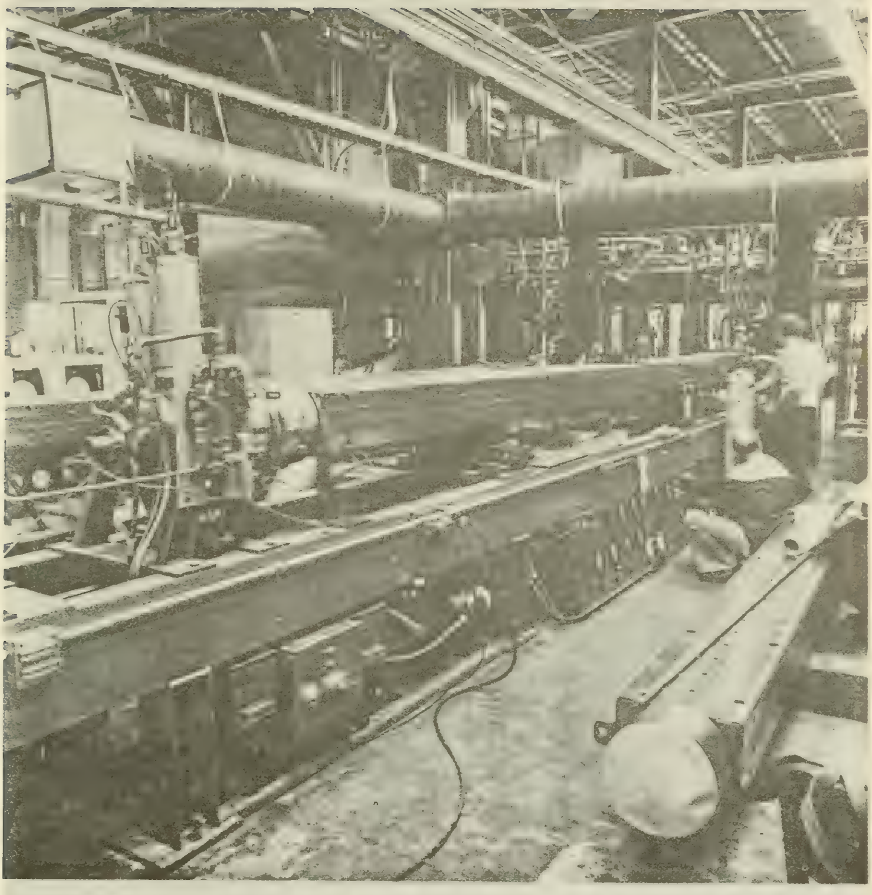
Carlos Hojvat with a dipole magnet for E-537 in P-West.



Welder Bruce Smith in Industrial 2 with a 63120 dipole magnet used in experimental area beam lines.

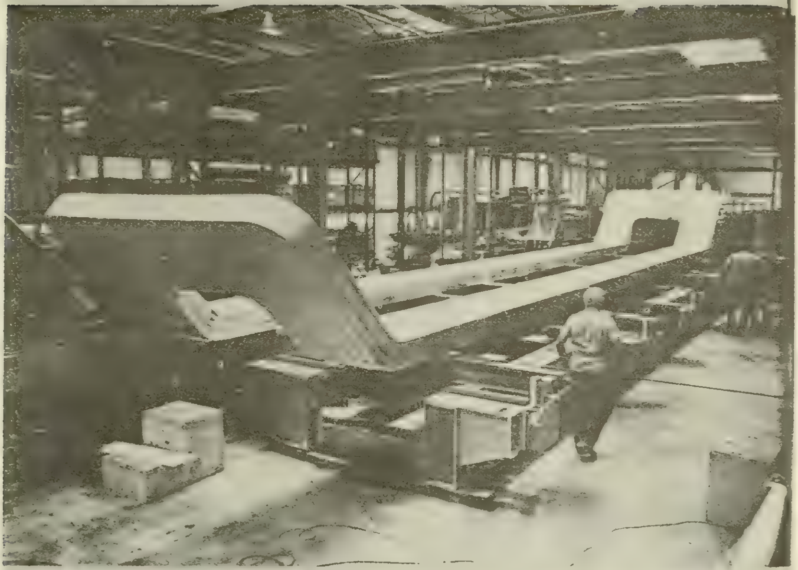
An overview of the Energy Saver dipole final assembly area at Industrial 1.

Bruce Kling, Dennis Ostrowski, Camillo Flores, and Steve Kluiwski assembling Saver cryostats at Lab 5 in the Village.

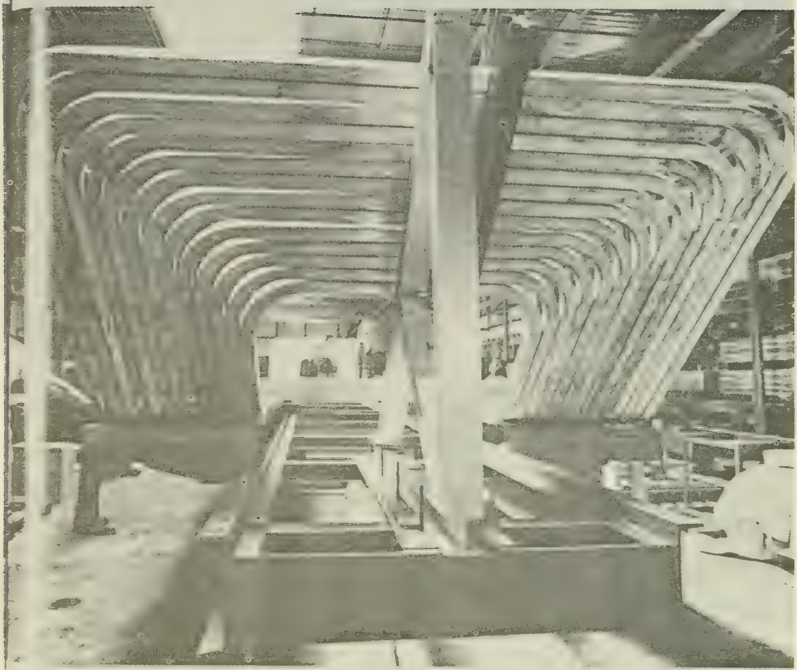


A test stand for Saver magnets at the Magnet Test Facility in Industrial 1.

Gary Andrews and Norm Leja stacking Saver magnets and spool-pieces at Industrial 4 prior to installation in the Main-Ring tunnel.



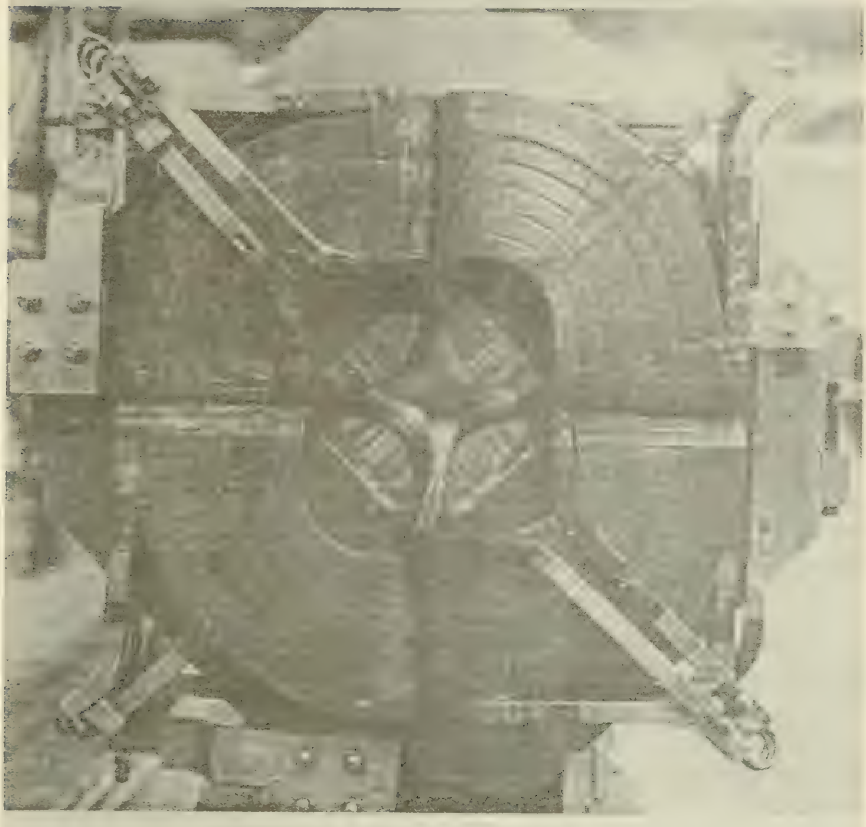
One of four coils for the E-605 dipole magnet being assembled in Industrial 4.



One of four coils for the E-605 dipole magnet being assembled in Industrial 1.

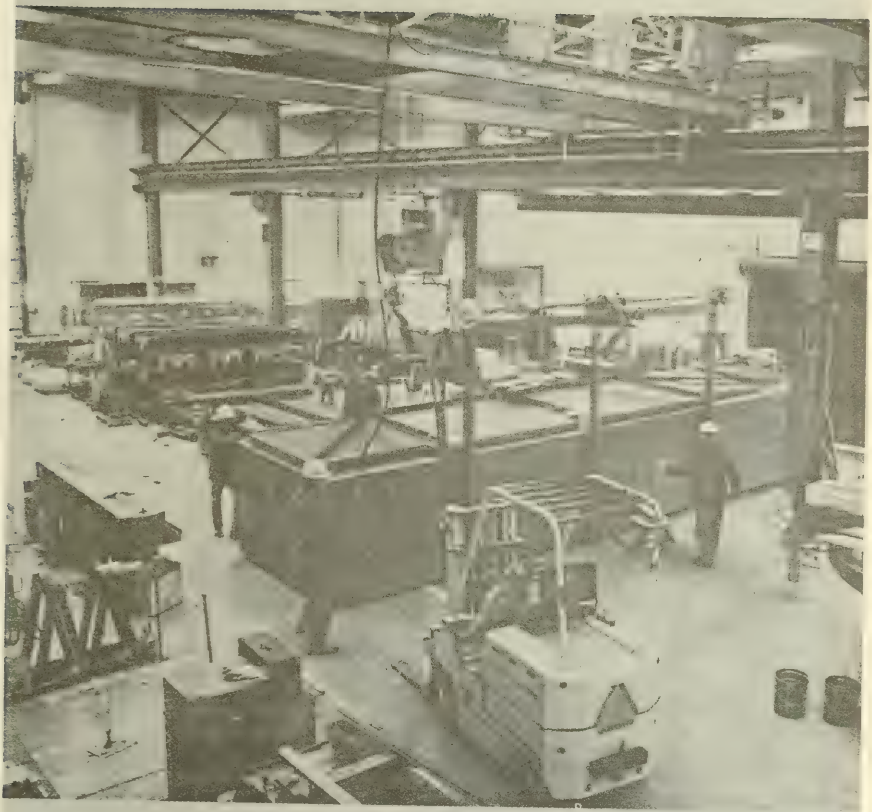
Jack Jagger with a coil for a TeV II 20-in. bump magnet.

Bill Strickland, Jr., brazing a water manifold on half of a large quadrupole magnet for TeV I.



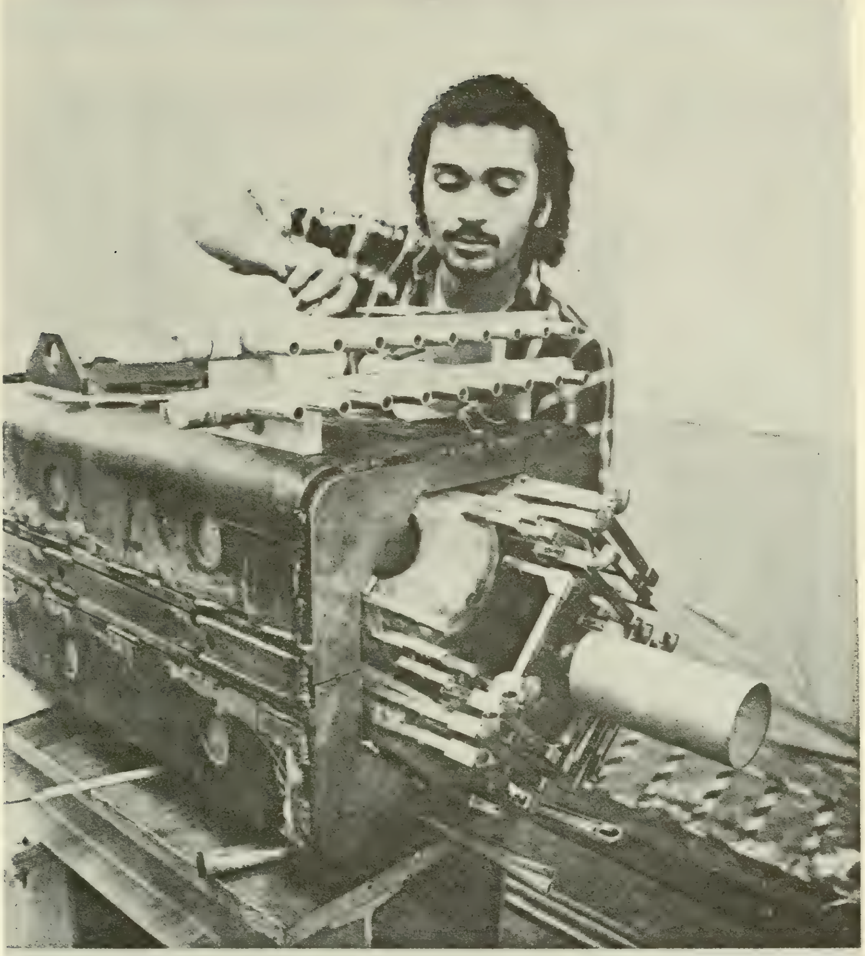
Looking down the center of the first TeV I small quadrupole magnet assembled at Paramount Park.

Jim Humbert with some of the small TeV I quadrupoles at the Paramount Park assembly plant.

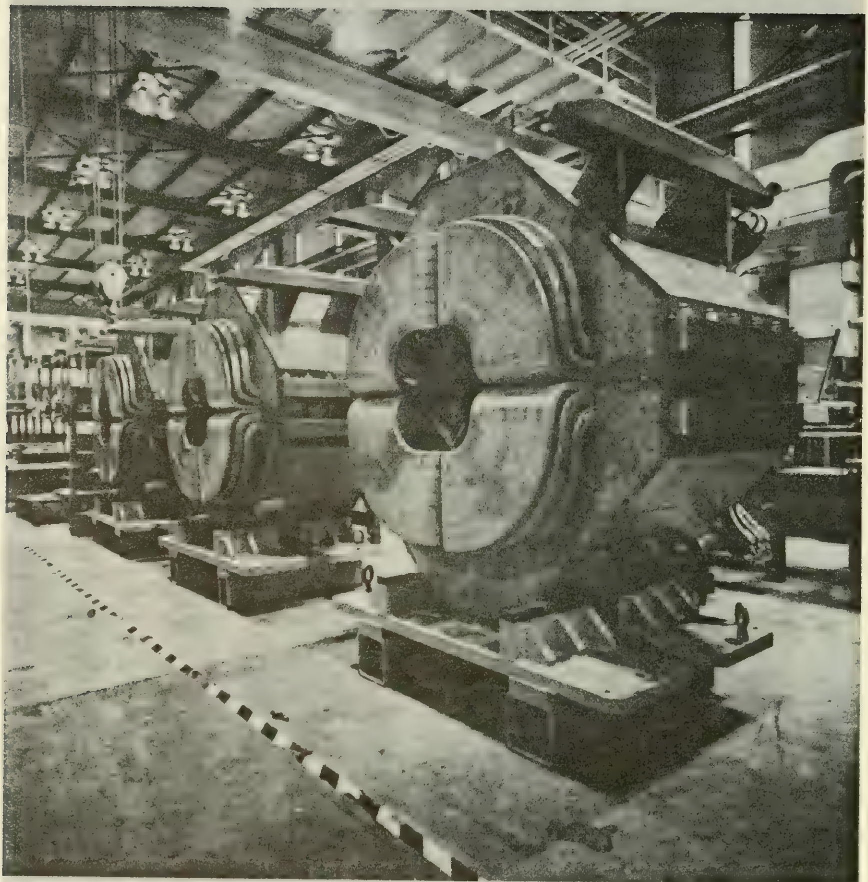


Moving the curing oven into Industrial 2.

Rolling-over a large TeV I dipole magnet half-core at Industrial Center.



Victor Ramierez working on a 3Q120A magnet for TeV I at the Paramount Park assembly plant.



Three completed TeV I quadrupole magnets at Industrial Center.

←

Welding on a Superconducting Supercollider prototype magnet at Industrial 3.


Fermilab
Direct Neutral Lepton Facility Workshop
12 October 1984
Fermi National Accelerator Laboratory
Batavia, Illinois
Fermilab
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Industrial
Participation
In Large
Science Projects
May, 1984
Dedication of the Energy Saver

VIII. Publications

Multiparticle #110

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15-Ft ν/H_2 & Ne #180

TOTAL ANTINEUTRINO-NUCLEON CHARGED CURRENT CROSS SECTION IN THE ENERGY RANGE 10-50 GeV. A. E. Asratyan et al., Phys. Lett. **137B**, 122 (1984).

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A MEASUREMENT OF THE MASS, FULL WIDTH, AND RADIATIVE WIDTH OF THE $B^+(1237)$ MESON. B. D. Collick, Ph.D. Thesis, University of Minnesota, April 1984.

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Particle Search #400

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Nuclear Fragments #442/#591

EXPERIMENTAL RESULTS FROM HIGH ENERGY PROTON NUCLEUS INTERACTIONS, CRITICAL PHENOMENA, AND THE THERMAL LIQUID DROP MODEL OF FRAGMENT PRODUCTION. A. S. Hirsch, Phys. Rev. **C29**, 508 (1984).

*This list was compiled using 1983 (not in **Fermilab 1983**) and 1984 journal articles, theses, and conference papers. Some conference papers were submitted to a conference prior to 1984 but were not published until 1984. If there are changes, omissions, or comments, please notify the Publications Office.

Particle Search #515

A STUDY OF CHARM PRODUCTION IN THE STRONG INTERACTIONS USING A PROMPT MUON TRIGGER. J. Bishop et al., **The Search for Charm, Beauty, and Truth at High Energies**, Proceedings of a Europhysics Study Conference on High-Energy Physics held November 15-22, 1981, in Erice, Sicily, Italy, Ed. G. Bellini and S. C. C. Ting (Plenum Press, New York and London, 1984), p. 545.

PRODUCTION OF LEPTONS IN COINCIDENCE WITH PROMPT MUONS. R. M. Edelstein et al., Phys. Rev. Lett. **53**, 1411 (1984).

Photoproduction #516

PHOTOPRODUCTION OF CHARM: RECENT RESULTS FROM THE TAGGED PHOTON SPECTROMETER. M. D. Sokoloff, Proceedings of the Ninth Hawaii Topical Conference in Particle Physics, Ed. E. Ma, August 11-24, 1983, p. 7.

A STUDY OF THE DECAY $D^0 \to K^-\pi^+\pi^-$ IN HIGH ENERGY PHOTOPRODUCTION. D. J. Summers, Ph.D. Thesis, University of California, Santa Barbara, March 1984.

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Dimuon #537

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SEARCH FOR HIGH-ENERGY TAU-NEUTRINO INTERACTIONS. H. C. Ballagh et al., Phys. Rev. **D30**, 2271 (1984).

HADRON UP-DOWN ASYMMETRY IN NEUTRINO-NEON CHARGED-CURRENT INTERACTIONS. H. C. Ballagh et al., Phys. Rev. **D30**, 1130 (1984).

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Neutrino #594

A MEASUREMENT OF THE ELASTIC SCATTERING CROSS SECTION $\nu_\mu + e^- \to \nu_\mu + e^-$. M. A. Tartaglia, Ph.D. Thesis, Massachusetts Institute of Technology, July 1984.

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FORWARD PRODUCTION OF CHARM STATES AND PROMPT SINGLE MUONS IN 278 GeV π^--Fe INTERACTIONS. J. L. Ritchie et al., Phys. Lett. **138B**, 213 (1984).

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MEASUREMENT OF THE DIJET CROSS SECTION IN 400-GeV pp COLLISIONS. M. W. Arenton et al., Phys. Rev. Lett. **53**, 1988 (1984).

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STATUS OF THE CCFR NEUTRINO OSCILLATION EXPERIMENT AT FNAL. D. Garfinkle et al., **Beyond the Standard Model**, Proceedings of the Leptonic Session of the Eighteenth Rencontre de Moriond, Vol. 2, Ed. J. Tran Thanh Van, La Plagne, Savoie, France, March 13-19, 1983, p. 77.

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NUCLEON STRUCTURE FUNCTIONS FROM HIGH ENERGY NEUTRINO INTERACTIONS WITH IRON AND QCD RESULTS. D. B. MacFarlane et al., Z. Phys. **C26**, 1 (1984).

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Chi Meson #705

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TRANSVERSE ENERGY PHYSICS WITH THE CDF CALORIMETER. J. Freeman, Proceedings of the 4th Topical Workshop on Proton Antiproton Collider Physics, Bern, Switzerland, March 5-8, 1984, p. 416.

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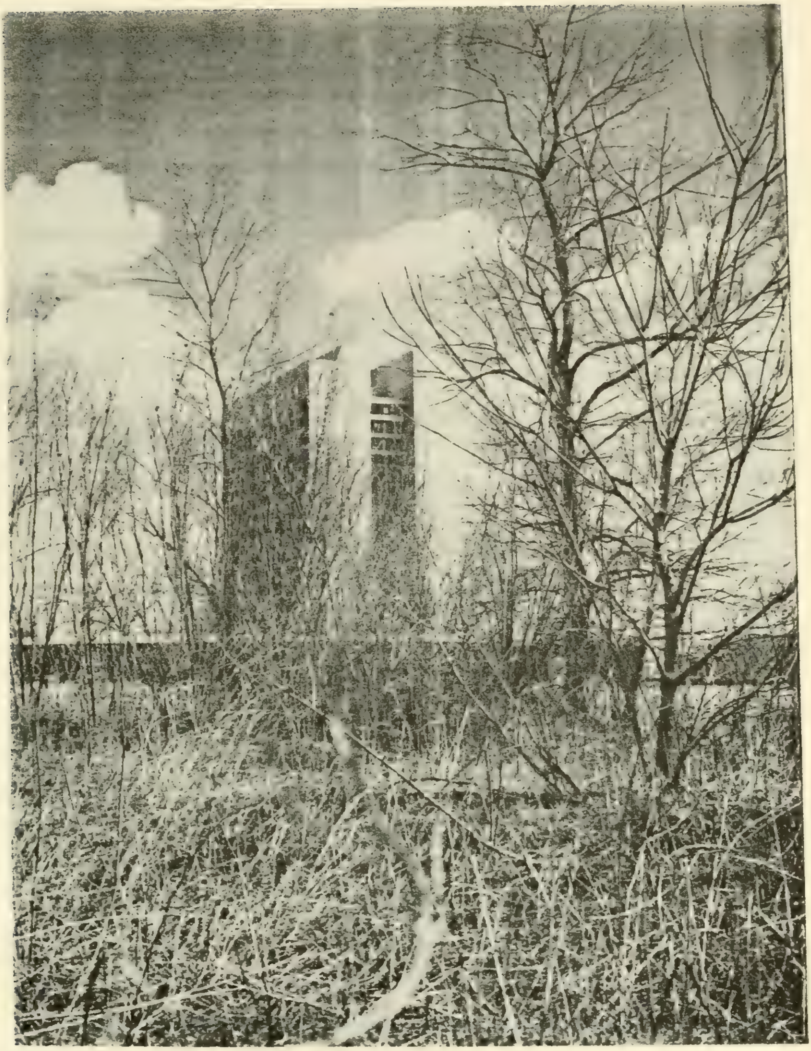

IX. 1984 Workshop and Seminar Series

Theoretical Physics Seminars

S. Nussinov, University of Pennsylvania, and Tel-Aviv, Israel: "Mass Inequalities in QCD," January 10, 1984

J. Sexton, Columbia University: "Local Lattice Fermion Actions," January 10, 1984

P. Kundu, University of Utah: "Spontaneous Symmetry Breaking in Cosmological Spacetimes," January 17, 1984

M. Rubin, University of Texas: "Dynamical Quantum Effects in Kaluza-Klein Theories," January 19, 1984

A. Pruisken, Schlumberger-Doll Research: "The Theta Vacuum Lives!--A Novel Explanation for the Integral Quantum Hall Effect," January 26, 1984

S. Chadha, Rutherford Appleton Laboratory, Chilton Didcot England: "Use of Chiral Lagrangians for Proton Decay," February 2, 1984

F. Green, Northeastern University: "The Confining Detransition," January 31, 1984

L. Smolin, University of Chicago: "Composite Higgs Bosons From an Extended Gauge Symmetry," February 7, 1984

X. Tata, University of Oregon: "Seeing SUSY," February 21, 1984

S. Das, Fermilab: "The Uses of Large N," February 28, 1984

M. Gunaydin, California Institute of Technology: "The Exceptional Supergravity Theories and the Magic Square," March 8, 1984

R. Pisarski, ITP, Santa Barbara, California: "Large N and Chiral Symmetries in Finite Temperature QCD," March 6, 1984

S. Libby, Brown University: "Quantized Hall Effect, Localization, and the Theta Vacuum," March 13, 1984

B. Svetitsky, Cornell University: "Lattice Gauge Theory at High Temperature," March 20, 1984

P. Lepage, Cornell University: "Effective Lagrangians for QED and QCD--A Renormalization Group Strategy for Bound States," March 27, 1984

G. Bhanot, Institute for Advanced Study: "Topology on the Lattice," April 3, 1984

S. Gupta, Institute for Advanced Study: "Problems with the New Inflationary Universe and A Possible Solution," April 10, 1984

K. Ellis, Fermilab: "Vector Boson Production at Collider and TeV I Energies," April 17, 1984

R. Jackiw, Massachusetts Institute of Technology: "Quantization of Physical Parameters," April 24, 1984

I. Antoniatis, Stanford Linear Accelerator Center: "Conformal Gravity and the Cosmological Constant," April 30, 1984

E. Farhi, Massachusetts Institute of Technology: "Strange Matter," May 8, 1984

J. P. Ralston, Argonne National Laboratory: "Chiral Calamity in the Skyrme Model," May 15, 1984

M. Veltman, University of Michigan: "Bound States of Vector Bosons," May 23, 1984

A. Kronfeld, Cornell University: "Lattice Analysis of Exclusive Processes and Deep Inelastic Scattering," May 24, 1984

Theory Group, Fermilab: "Discussion of the CERN "Zoo" Events," May 22, 1984

Jonathan Schonfeld, Fermilab: "Statistical Mechanics of Colliding Beams," May 29, 1984

Theory Group, Fermilab: "CERN Zoo Events: Theoretical Perspectives," May 31, 1984

S. Wadia, Tata Institute, Bombay: "The Low Energy Effective Lagrangian in QCD," June 5, 1984

C. P. Korthals Altes, CPT - CNRS, Marseille, France: "Gauge Fields in a Box, Zero Modes and Finite Size Effects," June 21, 1984

K. Olynyk, Ohio State: "A Gauge Invariant View of Symmetry Breaking," June 26, 1984

H. Steger, Max-Planck-Institute: "B-Meson Decay and CP Violation and Mixing in F and B Systems," July 3, 1984

A. Hasenfratz, University of Michigan: "Monte Carlo Renormalization Group Methods," July 10, 1984

O. Alvarez, University of California, Berkeley: "Geometry and Anomalies," July 17, 1984

C. Zachos, Argonne National Laboratory: "Topologically Induced Parallelization and I.R. Fixed Point," August 7, 1984

C. Schmid, Institute of Theoretical Physics, Eidgenössische Tech. Hochsch. Zurich, Switzerland: "Excitation and Decay of a Dyon and The Rubakov Callan Effect," August 14, 1984

K. Bitar, American Univeristy of Beirut, Lebanon: "Renormalization Flow of Lattice Gauge Actions," August 21, 1984

D. Caldi, Brookhaven National Laboratory: "Skyrmions and Vector Mesons: A Symmetric Approach," August 30, 1984

B. Kayser, National Science Foundation: "CP ad CPT Properties of Majorana Particles and Their Consequences," September 4, 1984

O. W. Greenberg, University of Maryland: "Nambu-Goldstone Fermions and Composite Models of Quarks and Leptons," September 11, 1984

A. Patrascioiu, University of Arizona: "Functional Integration on Compact Spaces," September 17, 1984

M. Gronau, Technion, Haifa, Israel: "Is CP Violation Maximal?" October 23, 1984

H. Hata, Kyoto University, Japan: "Color Confinement, BRS Symmetry and Negative Dimensions," October 25, 1984

U. Sarkar, University of Texas: "N = 2 SUSY and Compositeness," October 30, 1984

A. Jourjine, University of Wisconsin: "Dimensional Reduction as a Phase Transition," November 6, 1984

D. R. Yennie, Cornell University: "The Two Body Problem in Quantum Electrodynamics," November 13, 1984

S. Rao, Fermilab: "Fermions Interacting with Spherically Symmetric Monopoles," November 20, 1984

S. Elitzur, Hebrew University, Jerusalem: "Discrete Anomalies in Higher Dimensions," September 18, 1984

K. H. Streng, University of Munich: "Colored Weak Bosons: Possible Signals for Compositeness," September 25, 1984

M. Grady, Argonne National Laboratory: "An Improved Psuedo-Fermion Technique for Performing Monte-Carlo Simulation with Fermions," October 2, 1984

A. Masiero, CERN: "Split Light Composite Supermultiplets," October 9, 1984

L. Beaulieu, University of Paris: "Quantization of Generalized Gauge Theories in a Flat Space and Curved Space With or Without Local Supersymmetry," October 18, 1984

S. Shenker, University of Chicago: "String Compactification?" November 27, 1984

E. Mattala, ITP, Santa Barbara: "Thermodynamic Instability of deSitter Space," November 29, 1984

P. Hoyer, University of Wisconsin: "Gauge Covariant QCD Bound State," December 4, 1984

L. Mezincescu, University of Texas, Austin: "The σ - Model Interpretation of the Green-Schwarz Covariant Superstring Action," December 10, 1984

M. Green, Queen Mary College and Caltech: "Developments in Superstring Theory," December 11, 1984

Joint Experimental-Theoretical Physics Seminars

P. Meyers, Lawrence Berkeley Laboratory: "Nucleon Structure Function From Berkeley, Fermilab, Princeton Experiment," January 6, 1984

E. J. Siskind, NYCB Real-Time Computing Inc., and Cornell University Medical College: "Minimally Invasive Imaging of the Coronary Arteries in Man--An Operational VAX-Fastbus Experiment Outside of High Energy Physics," January 13, 1984

N. Giokaris, Fermilab: "Electron Scattering from Nuclear Targets," January 20, 1984

E. Paschos, University of Dortmund: "Charged Current Couplings and the Physics of the B-Mesons," January 27, 1984

M. M. Nieto, Los Alamos National Laboratory: "Physics at the Proposed National Underground Physics Facility," February 3, 1984

P. Drell, University of California-Berkeley, Lawrence Berkeley Laboratory: "Parity Non-Conservation in Atomic Transitions," February 10, 1984

S. Dawson, Lawrence Berkeley Laboratory: "Finding Supersymmetry in Colliders," February 17, 1984

J. Schonfeld, Fermilab: "What You Should Know (Things Your Mother Never Told You) About Colliding-Beam Storage Rings," February 24, 1984

T. Stanev, Bartol Research Foundation: "Things That People Really See In Proton Decay Detectors," March 9, 1984

D. Cline, University of Wisconsin: "Observation of Same Sign and Opposite Sign Dileptons At The CERN $p\bar{p}$ Collider," March 9, 1984

C. Quigg, Fermilab: "Super-Collider Physics," March 23, 1984

W. Hofmann, Lawrence Berkeley Laboratory: "Recent Results From the TPC at PEP," March 30, 1984

C. Matteuzzi, Stanford Linear Accelerator Center: "New Results from the Mark II Experiment," April 6, 1984

H. U. Martyn, I. Phys. Institute R. W. T. H., Aachen, Germany: "Recent Results From the TASSO Collaboration," April 13, 1984

M. Koshiba, University of Tokyo: "Results From The Kamioka Nucleon Decay Experiment," April 20, 1984

R. Bernstein, University of Chicago: "An Experimental Determination of ε'/ε In the Neutral Kaon System (E-617)," May 11, 1984

M. R. Whalley, University of Durham: "Data Compilations in HEP--The Durham--RAL Databases," May 18, 1984

N. Paver, ICTP, Trieste: "Multiple Parton Interactions and Multijet Events at Collider Energies," May 25, 1984

S. Fuess, Fermilab: "An Experimental Comparison of the Neutral Current Interactions to the Charged Current Interaction (E594)," June 1, 1984

J. Cooper, University of Pennsylvania: "Chi Production by Hadrons (E-610/673)," June 8, 1984

F. Dydak, CERN: "Recent CDHS Neutrino Results," June 14, 1984

T. Sjöstrand, University of Lund, Sweden: "New Developments in the Lund Jet Fragmentation Model," June 22, 1984

M. Anselmino, Indiana University: "Spin Dependence of the Fragmentation Process of Quarks and Gluons," June 29, 1984

D. Cline, University of Wisconsin: "Observation of Lepton + Multi-Jet Events in UA-1 Experiment and Search for the Top Quark," July 6, 1984

A. Zee, University of Washington, Seattle, Washington: "Dark Matter and Galaxies: An Overview," July 20, 1984

D. Lindley, Fermilab: "The Distribution of Matter in the Universe," July 27, and August 17, 1984

M. Bourquin, University of Geneva, Switzerland: "Baryons with Strangeness and Charm," August 10, 1984

B. Foster, Bristol University: "Lifetime Measurements and Experience with the TASSO Vertex Detector," August 31, 1984

G. Preparata, University of Bari: "Quarks in Collisions; e^+e^-, Lepton-Nucleon, $p(\bar{p})+p$," August 29, 1984

Assorted Members of the Theory Group, Fermilab: "The Zeta: Who Ordered That?" September 14, 1984

D. Klem, Stanford Linear Accelerator Center: "b-Lifetime Results from Delco," October 5, 1984

D. Carlsmith, University of Wisconsin: "K^{0*} (890) Radiative Decay Width," October 19, 1984

P. Grafstrom, Fermilab: "Electron Asymmetry from Polarized Σ- Beta Decay: A Critical Test of the Cabibbo Model," October 26, 1984

H. Tye, Cornell University: "Physics Interpretation of the Zeta," November 2, 1984

P. Reiner, University of Rochester: "Search for Anomalous Gravitational Effects at the Fermilab Accelerator," November 9, 1984

G. Giacomelli, University of Bologna: "Comparison of $\bar{p}p$ and pp at the ISR," November 5, 1984

J. Cronin, University of Chicago: "Direct Measurement of the π^0 Lifetime," November 16, 1984

R. Enomoto, University of Tokyo: "Evidence for the F^* Meson," November 20, 1984

N. Schmitz, Max Planck Inst., Munich: "W and Q^2 Depedence of Fragmentation Functions Measured in Deep Inelastic Leptoproduction," November 27, 1984

A. Yokosawa, Argonne National Laboratory: "Report on the International Symposium of High Energy Spin Physics at Marseille, France (Sept. 1984)," November 30, 1984

T. Nash, Fermilab: "Status Report on the ACP," December 14, 1984

L. Teig, Yale University: "Σ- Production Polarization and Magnetic Moment from E-497," December 21, 1984

Fermilab Colloquia

S. Brams, New York University: "'Approval Voting' A Better Way to Elect a President?" January 4, 1984

G. Yonas, Sandia National Laboratory: "A Modern View of Ballistic Missile Defenses," January 11, 1984

H. Kautzky, Fermilab: "Artificial Heart Valves," January 18, 1984

J. Hubbard, Cornell University: "Order and Chaos," January 25, 1984

P. Carruthers, Los Alamos National Laboratory: "Hadronization and Galaxy Counts: Examples of a Simple Stochastic Process," February 1, 1984

A. Crewe, University of Chicago: "Sub-Angstrom Electron Microscopy," February 7, 1984

L. Smarr, University of Illinois: "Exploring the Laws of Physics on a Supercomputer," February 8, 1984

M. Rees, University of Cambridge: "Evolution of Galactic Nuclei," February 15, 1984

F. Davidson, Massachusetts Institute of Technology: "Tunnels: Past, Present, and Future," February 22, 1984

S. Salzberg, Yale University: "Linguistics and Artificial Intelligence," February 29, 1984

J. C. Brandt, Goddard Space Flight Center: "U. S. Mission to Comet Giacobini-Zinner," March 7, 1984

T. Ackerman, NASA Ames Research Center: "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions," March 14, 1984

G. McDonough, Marshall Space Flight Center: "The Space Shuttle Main Engine Design," March 21, 1984

E. P. Krider, University of Arizona: "Lightning--A Diferent Kind of High-Energy Physics," March 28, 1984

C. Van Degrift, National Bureau of Standards: "Macroscopic Effects of Nuclear Spin in Solid ^{3}He," April 4, 1984

L. Nirenberg, New York University: "Remarks on Nonlinear Problems," April 11, 1984

F. Parke, New York Institute of Technology: "Overview and Trends in Computer Animation," April 19, 1984

A. Guth, Massachusetts Institute of Technology: "The Inflationary Universe," May 4, 1984

S. Jachim, AT&T Bell Labs: "Terrestrial Microwave Digital Radio: A Growing Information Age Telecommunication Medium," May 9, 1984

P. Diaconis, Stanford University: "The Statistics of Shuffling Cards," May 16, 1984

F. Filas, Loyola University: "Basics & Latest Research Updates on the Shroud of Turin," May 23, 1984

S. Manabe, Princeton University: "CO_2 and Climate," May 30, 1984

J. Thomson, Rand Corporation: "Deterrence & Strategic Defense," June 6, 1984

P. Handler, University of Illinois: "Volcanoes, Sea Surface Temperatures and Global Climate," June 13, 1984

R. Hansen, AT&T Bell Labs: "Computers and Networking in AT&T Bell Labs," June 20, 1984

D. Frey, Bell and Howell: "Managing the Innovative Organization," June 27, 1984

J. H. McAlear, Gentronix, Inc.: "Biomolecular Electronics," September 13, 1984

C. Persson, Jet Propulsion Laboratory: "Infrared Astronomy Statellite," September 26, 1984

H. Davidson, Lawrence Livermore Laboratory: "How to Put a Cray I in a Tuna Fish Can and Make It Run Faster," October 3, 1984

C. F. Ehret, Argonne National Laboratory: "Circadian Clocks at the Base of Life: Recent Advances in Chronobiology and Chronobiotechnology," October 10, 1984

L. G. Mollenauer, Bell Lab: "Solitons in Optical Fibers and the Soliton Laser," October 17, 1984

E. Commins, University of California, Berkeley: "Parity Nonconservation in Atomic Thallium," October 24, 1984

A. T. Winfree, Purdue University: "3D Wave Topology in Excitable Media (the human heart, for example)," October 31, 1984

F. E. Dalton, Metropolitan Sanitary District of Greater Chicago: "Status of Chicagoland Tunnel and Reservoir Plan (TARP)," November 7, 1984

A. K. Dewdney, University of Western Ontario: "The Planiverse," November 14, 1984

P.G.O. Freund, University of California: "Modern Kaluza-Klein Theory," November 28, 1984

M. Mathews, AT&T Bell Labs: "Studies of Violin Tone by Electrical Simulation of the Resonances of the Violin Body," December 5, 1984

J. P. Kempton, Illinois State Geological Survey: "The Role of Geology in Siting Studies in Illinois; The Proposed SSC, A Premier Example," December 12, 1984

E. Carlson, Department of Biochemistry, New York: "H. J. Muller: Gadfly of Science," December 19, 1984

R. Bond, Stanford University: "Dark Matter and Cosmic Background Radiation Anisotropies," November 12, 1984

R. Juszkiewicz, University of California, Berkeley: "The Large-Scale Structure of the Microwave Background Radiation," December 3, 1984

J. Preskill, Caltech: "Voids as Fluctuations," December 17, 1984

Theoretical-Astrophysics Seminars

S. Barr, University of Washington: "Euclidean Chiral Fermions," January 16, 1984

A. Chodos, Yale University: "Quantum Aspects of Kaluza-Klein," January 30, 1984

M. Perry, Princeton University: "Kaluza-Klein Monopoles," February 6, 1984

M. Hereld, Caltech: "Gravity Waves and the Caltech Laser Interferometer," February 8, 1984

P. Sikivie, University of Florida: "Axionia," February 13, 1984

A. Vilenkin, Tufts University: "Creation of Universes from Nothing," February 27, 1984

I. Wasserman, Cornell University: "Plasma and Gravitational Dynamics of a Monopole Halo," March 12, 1984

G. Chapline, Lawrence Livermore National Laboratory: "Unification of Elementary Particle Physics and Cosmology in 10 Dimensions," March 19, 1984

N. Weiss, University of British Columbia: "Evolution Equations for the Higgs Field in a Hot, Expanding Universe," April 9, 1984

F. Graziani, University of Colorado: "Fragmentation in Molecular Clouds," April 9, 1984

F. Cooper, Los Alamos National Laboratory: "An Improved Method for Studying False-Vacuum Decay," April 19, 1984

S. Y. Pi, Boston University: "Inflation Without Tears," April 23, 1984

C. Hogan, Caltech: "Astrophysics of Strings," May 7, 1984

R. Rood, University of Virginia: "^{3}He Abundances," May 14, 1984

F. Cordova, Los Alamos National Laboratory: "EXOSAT X-Ray Observation of Close Binary Systems," May 21, 1984

B. Carr, University of Cambridge: "Pre-Galactic Stars and the Dark Matter Problem," October 1, 1984

J. Hills, Los Alamos National Laboratory: "Comet Showers and Nemesis the Death Star," October 15, 1984

N. Turok, ITP, Santa Barbara: "Self-Similarity of Cosmic Strings," October 22, 1984

T. Allen, University of Michigan: "Late Evolution of Cosmological Structure," October 29, 1984

Research Technique Seminars

A. Vorobiev, Leningrad Nuclear Physics Laboratory: "E715 Transition Radiation Detectors," February 16, 1984

D. Anderson, Fermilab: "Some New Ideas in Detectors," February 23, 1984

R. A. Holroyd, Brookhaven National Laboratory: "Physics and Chemistry of Room Temperature," March 8, 1984

G. Coutrakon, Fermilab: "Ring Imaging Cerenkov Results Using Multi-Needle Detectors," March 22, 1984

M. Atac, Fermilab: "Breakdowns, Sparks, Rates and Long Lifetimes," March 29, 1984

D. Kaplan, Fermilab: "A 40 MHz, Parallel, Pipelined Event Processor for E-605," April 19, 1984

P. Mangeot, Saclay: "Can Detectors Combined with Indium Targets Help Solar Neutrino Puzzle?" April 26, 1984

A. Breskin, Weizmann Institute: "New Prospects with Low Pressure Gaseous Detectors," May 3, 1984

M. Atac, Fermilab: "Radial Drift Chamber for the CDF," May 10, 1984

L. Holloway, University of Illinois: "High Precision Charge Division for the CDF," May 10, 1984

S. Majewski, Fermilab: "Thin Multiwire Chambers in the Highly Saturated Mode," May 31, 1984

P. Rehak, Brookhaven National Laboratory: "High Resolution Germanium Drift Detector," June 21, 1984

K. Peach, CERN: " Experience with FASTBUS at CERN," October 17, 1984

M. Panter, CERN: "High Density Projection Chamber Calorimeter for the DELPHI Experiment," October 24, 1984

P. Sharp, Rutherford and Appleton Laboratories: "Ring Imaging Cherenkov Detector for the CERN OMEGA Spectrometer," October 25, 1984

A. Policarpo, Universidade de Coimbra, Portugal: "The Gain Divergence at the Transition to the Self-Quenching Streamers," October 26, 1984

G. Harigel, CERN-EF: "Argon Bubble Chamber for Fixed Target Experiments at Multi-TeV Accelerators," November 29, 1984

G. Coutrakon, Fermilab: "Ring Imaging Cherenkov Results Using a Wire Chamber with Cathode Pad Readout," December 6, 1984

Arms Control and International Security Seminar Series

G. Yonas, Sandia National Laboratory: "A Modern View of Ballistic Missile Defenses," January 11, 1984

R. D. Woodruff, Lawrence Berkeley Laboratory: "Arms Control and Strategic Options for the 1990's," February 9, 1984

T. Ackerman, NASA Ames Research Center: "Nuclear Winter: Global Consequences Center of Multiple Nuclear Explosions," March 14, 1984

Workshops

Inner Space/Outer Space Workshop on High Energy Physics,
Astrophysics, and Cosmology
May 2-4, 1984

Fermilab Workshop on Fixed Target Physics
June 9, 1984

Vertex Detectors: Charm and Beauty I Workshop
September 21-22, 1984

Direct Neutral Lepton Facility Workshop
October 12-13, 1984

Hyperon Physics at the Tevatron Workshop
December 7-8, 1984

Other

Fermilab Users Annual Meeting
April 27-28, 1984

Dedication of the Energy Saver
April 28, 1984

Fermilab Industrial Affliates Annual Meeting
May 24-25, 1984

U. S. Summer School on High Energy Particle Accelerators
August 13-24, 1984

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Frontispiece: "The Stars", English copper engraving from the 18th century. Bibliotheque l'Observatoire.

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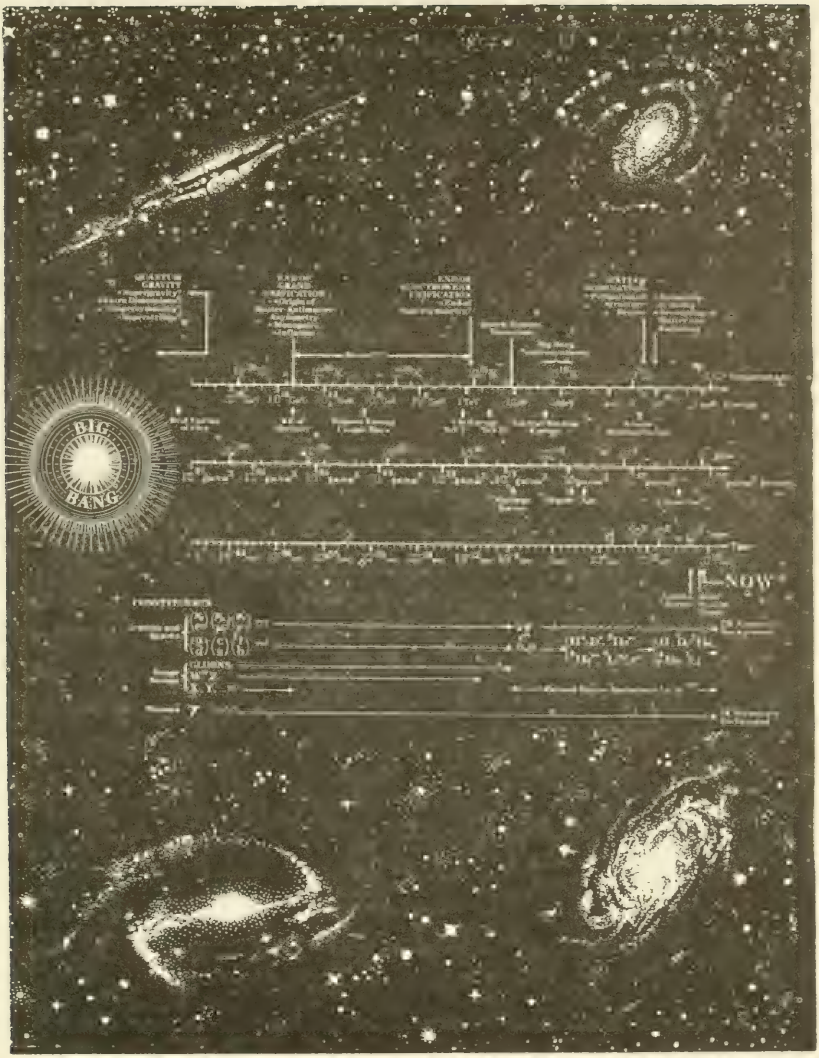
Page 11 illustration: "Creation of the World", 17th century copper engraving. Akademie, Wien.

Back cover: "History of the Universe." Fermilab.

The History of the Universe

With Newton's discovery of the universality of gravity came the realization that in our laboratories we can study, measure, and quantify the force responsible for the movements of the celestial bodies, and gain knowledge and understanding in an area that was thought to be forever outside the realm of human comprehension. Today, in collisions of particles at high-energy accelerators, we are able to create conditions of energy, temperature, and pressure that are similar to the conditions obtained in the earliest moments of the big bang. As we explore physics at higher energies we are able to explore the Universe at times closer to the moment of the big bang. The understanding of the behavior of matter under extreme conditions, and the knowledge of the fundamental constituents of matter allow us to understand the Universe as early as 10^{-12} seconds after the bang. Theoretical speculation allows us to make an outrageous extrapolation of our understanding of the Universe back to the time of the big bang itself. We present the "History of the Universe" as it reflects our present understanding. Physicists of the 22nd century will no doubt look upon our "History of the Universe" with the same amusement with which we look upon astronomical texts of the 18th century. We only hope that they see boldness and imagination in our attempts to study the origin of the Universe and to bring into the realm of human understanding yet another area once thought to be beyond our grasp.

-E. Kolb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HIGH ENERGY PHYSICS INSTITUTIONAL PLAN

FY 1985 - FY 1990

Under Contract with the
Department of Energy
Contract DE-AC03-76SF00515

February, 1985

STANFORD LINEAR ACCELERATOR CENTER
Stanford University Stanford, California

SLAC Institutional Plan FY1985 - FY1990

Stanford Linear Accelerator Center

Institutional Plan

FY1985 - FY1990

Contents

I. DIRECTOR'S STATEMENT

A. Introduction

This Institutional Plan is an attempt to describe research in which SLAC will be engaged during the period from 1986 to about 1990, the facilities that will be used to carry out that research, and the resources that will be needed to support the program. As might be expected in a field that continues to evolve very rapidly, our plans for the latter part of the projected period are subject to a good deal of uncertainty. The SLAC program will continue to be guided by new physics results worldwide.

B. Overview

(1) Program. During the past decade the primary focus at SLAC has gradually shifted from fixed-target experiments to experiments that make use of colliding beams of electrons and positrons. This shift is expected to continue with the advent of the SLC. This shift has been driven not only by scientific judgment but also by budgetary constraints. Much interesting physics remains to be done in areas of investigation that have been severely curtailed or entirely abandoned for largely budgetary reasons. The SLAC physics program is addressed in some detail in Section IV of this Plan, which also includes a description of SLAC's research and development activities in the fields of detector and accelerator technology.

Construction of the SLAC Linear Collider (SLC) has advanced in a satisfactory manner, and progress continues to be compatible with its planned completion date of late 1986. The SLC serves the dual objective of pioneering a new electron-positron collider technology while at the same time providing access to the 100 GeV center-of-mass energy region where the highly productive physics of the Z^0 intermediate boson will be studied. It is anticipated that in 1989 the European machine LEP will enter operation with an initial complement of four detectors. SLC will continue to support viable physics research at its single in-

teraction point in the LEP era because it offers singular opportunities based on polarized beams, the possibility of electron-electron collisions, and the possibility of observations close-in to the interaction point which are not available at LEP.

Given these prospects for the SLC, and the fact that a great deal of important research remains to be done with the existing PEP and SPEAR storage rings at SLAC, we have made the following major program assumptions for the period from 1986 to 1990:

(a) The SLC will begin operating in FY1987 and will continue throughout the period of this projection.

(b) PEP will continue operating through 1990, with upgraded performance expected in 1986 or 1987. (Note that the comparable German machine PETRA will cease operating for research in 1986, leaving PEP as the only electron-positron facility in this energy range.)

(c) SPEAR will continue operating through 1990. (Note that the comparable BEPC machine in the Peoples Republic of China is scheduled to begin operating in 1988. The long-term future of SPEAR will be reviewed at that time.)

(d) Beginning in FY1987, the operating schedule of the SLC will be 650 shifts annually. SLAC itself will operate 800 shifts annually, with the additional shifts devoted to nuclear physics research, SPEAR operation including synchrotron radiation research, and possibly to PEP operation for synchrotron radiation research or special high energy physics experiments.

(e) The remodeled Mark II detector will be available for SLC physics early in 1987. The new SLD detector will provide enhanced experimental opportunities at the SLC after its completion in 1989.

(f) Advanced Accelerator R & D at SLAC will receive increased emphasis in 1987 as scientific staff becomes available after completion of the SLC.

(2) Scientific Staffing and Use of the SLAC Facilities. The total number of experimental physicists active in U.S. high energy physics continues at a level of

approximately 1100, and we do not foresee a significant change in this number during the period of this projection. Opportunities for high energy physics data collection in the U.S. continue to be divided among work at Brookhaven, Fermilab, Cornell and SLAC, in addition to activities not using accelerators. During the period covered by this plan there is some uncertainty about the level of work at Brookhaven. The work at Cornell involves a relatively small number of physicists. Fermilab is resuming an active particle physics program using the newly completed Tev II and Tev I facilities, but a large backlog of experiments is now in the queue. As a result of this national pattern, as well as the opportunities at SLAC, we envisage a substantial growth in the number of physicists active in the SLAC experimental program.

Consistent with the recommendations of SLAC's Scientific Policy Committee, the number of SLAC and other Stanford University experimental physicists will be permitted to increase from the current number of 75 full-time equivalents to about 80 by 1986 (the total number of individuals involved will approach 100). At the same time, a survey of the experimental opportunities and needs in 1986 indicates that a total of about 580 experimentalists will be active at SLAC. Of these, perhaps 75 will come from foreign countries. We anticipate that this increase in user population will intensify our already severe space and other support problems.

Principally because of the increased load imposed by the SLC, we anticipate that our total regular personnel will grow by about 15% during the projection period. We will adjust this growth so that it matches our total needs after completion of the SLC. We are accommodating the peak personnel load during the construction period through a combination of temporary employees and subcontracts. We also expect to continue the practice of using temporary employees during the summer construction periods.

(3) Funding Pattern. The staffing projections discussed here are consistent with the funding pattern we experienced in the past as we added new facilities to

SLAC. As shown in Figure I-1, our recurrent funding pattern measured in fixed purchasing power dollars had a steady decrease from the beginning of operation in 1967 until 1975. It then leveled off throughout the construction period of PEP and reached a plateau approximately 15% higher after PEP was completed.

A summary projection of SLAC baseline funding through FY1990 is provided in Table I-1.

(a) Operations: The President's Budget for FY1986 fails to cover inflation and is therefore not adequate to carry out planned high energy physics programs at SLAC. The Baseline Projection assumes that from FY1987 on SLAC will receive financial support adequate to maintain a balanced high energy physics research program, including an appropriate level of investment in the future in the form of advanced accelerator and detector R & D.

Power rates have very large leverage on our future. In particular, the advent of the SLC is expected to increase our annual power consumption from its current value near 230,000 megawatt hours to a value near 400,000. The financial implications of this increased consumption depend greatly on the arrangements and rates that will be in effect beginning in 1987, both from the private utility and from the Western Area Power Administration.

(b) Capital Equipment: Our capital equipment needs can be divided into two categories:

(1) Perennial Equipment Needs: We must provide for a base level of general laboratory equipment, typically \$ 3 million annually. Another \$ 3 million to \$ 4 million is required for improvements to existing detectors and for replacement of equipment required by the laboratory's program of scientific inquiry.

(2) Major Acquisitions: The requirements of the SLC detector program impose extraordinary pressure on SLAC equipment resources through FY1989: Mark II is being renovated for relocation to SLC at a total cost of \$ 11 million (\$ 9.3 million of which is an expenditure of FY1984 or later); and the SLD has

Figure I-1

FUNDING SUMMARY INCLUDING
NON-RECURRENT FUNDING
1985 Dollars in Millions

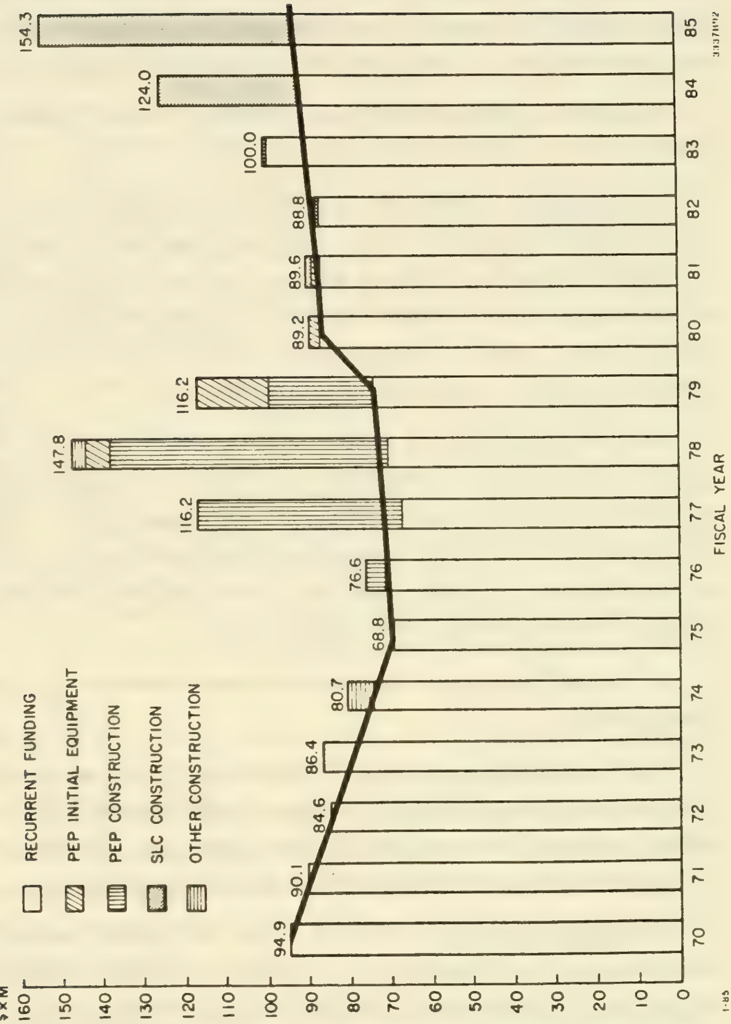


Table I-1

LABORATORY SUMMARY
Baseline Program

FUNDING ($ in Millions)	FY1983	FY1984	FY1985	FY1986	FY1987	FY1988	FY1989	FY1990
Total Operating	77.6	74.0	79.5	83.1	109.6	117.4	131.1	140.2
Capital Equipment	7.0	8.0	9.5	11.3	27.8	26.5	19.8	11.4
Construction	3.3	35.2	65.5	27.4	4.7	4.7	4.7	4.7
Total for Laboratory	87.9	117.2	154.5	121.8	142.1	148.6	155.6	156.3
PERSONNEL (Personnel in FTE)								
Direct Personnel	944	1005	1098	1190	1200	1200	1200	1200
Indirect Personnel	349	333	327	340	340	340	340	340
Total Laboratory Personnel	1293	1338	1425	1530	1540	1540	1540	1540

1) FY1983-FY1985 actual funding in then year dollars.

2) FY1986 funding from President's Budget

3) FY1987-FY1990 estimated funding in constant FY1986 dollars.

a price tag of approximately \$ 56 million including approximately \$ 6 million of non-SLAC funds.

The SLAC computer will once again be saturated by the time the SLC becomes operational, and it will be necessary to procure a replacement at an estimated cost of \$ 7.5 million.

The SLAC telephone system is archaic and simply has to be replaced soon. The cost of replacement will be approximately \$ 3 million (in FY1985 dollars), probably incurred during FY1986. Both the computer and telephone acquisitions may have to be lease/purchase arrangements.

SLAC's projected equipment needs are summarized in Table I-2.

(c) Line Item Construction Projects: The major SLAC construction project for the period of this plan is the SLAC Linear Collider. This project, with a total estimated cost of \$ 113 million, is a prominent feature of the nation's particle physics program, and will produce e^+e^- collisions in the 100 GeV range.

(d) Space Needs: As stated in the section on scientific staffing above, the laboratory anticipates a substantial increase in resident staff and visiting scientists. We currently have urgent need for more office and light laboratory space, and the expected increase in population will aggravate that condition. The laboratory projects a shortfall of 53,000 square feet of office and light laboratory space by FY1989. An earlier proposal for a Central Laboratory Expansion would have provided nearly 75% of this requirement, at a cost in FY1984 dollars of \$ 5.4 million. We have not, however, been encouraged about the prospects of this proposal, and it will not be re-submitted. Nevertheless, laboratory management considers the space problem to be quite critical, and we have decided to relieve our overcrowding with a series of GPP Projects that will satisfy at least part of this need by 1990. This is done with great reluctance: there continues to exist a queue of unsatisfied general plant improvements that have been deferred because of space needs.

Table I-2

SLAC HEP EQUIPMENT FUNDING

Minimum Needs Showing
SLD to 1989 Completion
(in Thousands of Dollars)

	FY1985	FY1986	FY1987	FY1988	FY1989	FY1990
Experimental Detectors other than SLD	4,300	3,300	3,600	1,800	5,500	5,500
Mark II	3,300	2,100	1,000	300	--	--
PEP & SPEAR Detectors	1,000	1,200	2,200	500	500	500
Other Physics Initiatives	--	--	400	1,000	5,000	5,000
Accelerator & Facilities	1,500	2,100	5,300	2,300	1,600	1,600
PEP Luminosity Upgrade	500	500	2,200	--	--	--
Minor Mods & Imp.	250	--	1,800	800	800	800
SLC (Pre-completion)	500	--	--	--	--	--
SLC General	--	600	400	--	--	--
SLC Polarization Project	--	--	1,300	1,000	--	--
SLC Shielding	--	1,000	--	--	--	--
AARD	250		--	500	800	800
Computing	500	500	900	800	800	800
General Laboratory	1,500	1,400	2,100	3,000	3,000	3,000
Subtotal	7,800	7,300	11,900	7,400	10,900	10,900
Desired SLD	1,700	4,000	14,700	17,900	8,000	0
Total with SLD Funding	9,500	11,300	26,600	25,300	18,900	10,900

Notes

1) No provision for large CPU acquisition or telephone system upgrade.
2) Minimum estimates for new physics initiatives.
3) Minimum estimates for PEP detector (presumed TPC and HRS upgrades or retrofits).
4) Minimum estimate for general laboratory needs.
5) FY1985 actual funding in then year dollars.
6) FY1986 from President's Budget.
7) FY1987-FY1990 in constant 1985 dollars.

II. LABORATORY MISSION

The Stanford Linear Accelerator Center is dedicated to research in high energy particle physics and to the development of new techniques in high energy accelerators and experimental apparatus. The center is operated as a national facility so that scientists from universities and research centers throughout the world may participate in the high energy research program.

The mission of SLAC can be summarized as follows:

1. To provide accelerator facilities to carry out experimental research in high energy physics.

2. To provide detection devices to exploit the accelerator facilities.

3. To provide the necessary support for groups of physicists from SLAC and from other institutions to carry out experiments.

4. To carry out experimental and theoretical research in high energy physics.

5. To develop new detection techniques in order to allow new kinds of experiments to be done.

6. To develop, through accelerator R & D, methods to improve the capabilities of existing accelerators at SLAC and elsewhere.

7. To develop, through advanced accelerator R & D, the conceptual framework and technology needed to make very high energy electron-positron colliders practical and cost-effective.

8. To assist scientists in other disciplines to exploit special opportunities that may arise from our high energy physics facilities.

III. MAJOR LABORATORY ISSUES

There are four pervasive issues currently confronting this laboratory that merit exposition in this section of the Institutional Plan. Taken in their general order of immediacy to current program management, they are:

(1) The level and balance of funding available for program support;

(2) Availability of space to house the SLAC staff and user community;

(3) The future availability and cost of electrical power to conduct a vigorous experimental program; and

(4) Whether or not the laboratory should embrace other programs of substantial size in addition to high energy physics.

A. Funding Issues

In many respects, of course, the other issues are specific subsets of the broad funding issue, since most of the concerns associated with each of the others would be obviated by the availability of unlimited funds. We choose, however, to acknowledge that an existence unconstrained by funding limitations is highly improbable, and to address the issues as if each were independent of the others.

On the one hand, the number of centers for particle physics research is small, and opportunities for the practitioners of the art are therefore rather limited. And yet, even those few accelerators that support this research are dramatically underutilized, depressing the productivity of the nation's physics throughput. And the physics done is, of course, the real payback on the huge investment. It is clear that the laboratories need an increase in operating support.

On the other hand, however, the goal of high energy physics is to extend the frontiers of knowledge, and some would assert that a policy which emphasizes exploitation of existing resources to the disadvantage of innovative new investment is a decision for a terminal program. A major problem is that as the frontiers of research move to ever higher energies, the investment required to reach the next

energy plateau increases. Furthermore, the detectors now required to do competitive physics begin to approach the particle accelerators themselves in complexity and cost. Juxtaposing the cost of a large particle detector upon the cost of an accelerator construction project (they must both be available at approximately the same time in order to do physics) produces a major bump in a laboratory's funding profile, and offends the senses of those who feel that support of the field should approximate a smooth continuum. *The* major issue facing SLAC then, is how to strike a proper balance between exploitation of existing facilities and development of new ones. It has not been adequately resolved.

Total SLAC resources by program are summarized in Table III-1.

B. Light Laboratory and Office Space

An insufficiency of light laboratory and office space to house the SLAC staff and resident user community has been a chronic problem in recent years. The SLAC staff continues to grow at approximately 2 to 4 % annually, and the user community has nearly tripled since 1978 without a commensurate increase in support space. Section V.B addresses this issue in some detail and outlines the strategy adopted to deal with the problem.

C. Electrical Power

SLAC draws its electrical energy from two sources. The first 45.3 megawatts of instantaneous demand is supplied by the Western Area Power Administration at an average cost of approximately 2 cents per kilowatt-hour and any demand beyond that level is supplied by Pacific Gas and Electric Company at an average cost of approximately 6 cents per kilowatt-hour. There is obviously an incentive for SLAC to manage its operations such that PG & E power usage is minimized. Load management is complicated, however, by a rather complex (and clumsy) WAPA load shedding procedure during peak load periods, and will become more difficult in the not too distant future when SLC operations will routinely push SLAC demand above the PG & E threshhold. We are, needless to say, keenly interested in any potential increase in our WAPA power allocation,

Table III-1

RESOURCES BY PROGRAM
(In Millions of Dollars)

Program Name	FY1983	FY1984	FY1985	FY1986	FY1987	FY1988	FY1989	FY1990
Operating								
High Energy Physics	77.6	73.9	78.4	81.6	107.2	114.5	127.5	136.3
Nuclear Physics	0	0.1	1.1	1.5	2.4	2.9	3.6	3.9
Total Operating	77.6	74.0	79.5	83.1	109.6	117.4	131.1	140.2
Capital Equipment	7.0	8.0	9.5	11.3	27.8	26.5	19.8	11.4
Construction	3.3	35.2	65.5	27.4	4.7	4.7	4.7	4.7
Total for Program	87.9	117.2	154.5	121.8	142.1	148.6	155.6	156.3
Direct Personnel	944	1005	1098	1190	1200	1200	1200	1200

1) FY1983-FY1985 actual funding in then year dollars.

2) FY1986 funding from President's Budget.

3) FY1987-FY1990 estimated funding in constant FY1986 dollars.

and we are strongly supportive of the proposed Pacific Tieline interconnect to take advantage of some of the excess capacity of the Bonneville system. SLAC energy consumption and related issues are dealt with in more detail in Section V.D.

D. Primary Programs Other Than High Energy Physics

Since its inception, SLAC has been a single-function laboratory dedicated entirely to high energy particle physics. At various times questions have arisen as to whether this status should continue. For example, the issue was raised whether SLAC, in view of its specialized facilities and experienced staff, could serve parts of the national applied energy program. After extensive discussion, the decision was reached that SLAC should undertake non-high energy physics work only where it could be of assistance, based on its specialized resources, to specific outside projects on a "work for others" basis, but that it would not take independent responsibility for any areas of science and technology outside the high energy particle physics area. The matter arose again in the early 1970's when the copious production of synchrotron radiation from the storage ring SPEAR provided a unique national opportunity for the utilization of that radiation, both in the ultra-violet and x-ray regions. It was then decided to establish the Stanford Synchrotron Radiation Laboratory (SSRL) as an independent entity within Stanford University, originally under contract to the National Science Foundation. SLAC retained its single-function status at that time under an agreement involving the government agencies concerned and SSRL. It was agreed that SLAC would supply certain services on a reimbursable basis and that initial operation of SSRL would be purely parasitic, that is, incidental to the operations of SPEAR for high energy physics. Subsequently, an agreement was reached for one-half of the operation of SPEAR to be dedicated specifically to synchrotron radiation use by SSRL, while parasitic use could continue during the other half. This arrangement is still in force. SSRL is also planning to construct an access tunnel to a port of the PEP storage ring to explore the possibility of synchrotron radiation research using that machine.

The single-function status of SLAC has served the laboratory and the scientific community well, and we believe it has also been to the overall advantage of the government. It makes possible simplified organization and management, and it avoids unnecessary layers of review within the organizational structure of SLAC by individuals not familiar with the technical content. The program responsibility is held within a single division of DOE, and the fundamental mission of the laboratory remains unambiguous. These advantages notwithstanding, the recent expansion plans of SSRL again raised the question of the single-function future of SLAC. This matter is under review, but even if a change were made, it would have minimal implications on the high energy physics program projections.

Aside from the SSRL issue, a new non-high energy physics program was initiated during 1984. This program is based on the utilization of the spectrometers and associated equipment currently located in End Station A with a lower energy beam (up to 6 GeV) produced by a new off-axis injector located about 400 meters from the end of the two-mile accelerator. This low energy beam can be operated at much lower cost than is involved in operating the entire accelerator. Accordingly, it will also be possible to make this low energy beam available during the summer months when usually, owing to the high electrical summer demand in the state of California, the laboratory does not operate its major facilities. The low energy beam can serve not only the nuclear structure program but can also be used to fill the storage ring SPEAR, thereby increasing the total amount of time available for SSRL and HEP research. Since the scale of operation of the nuclear physics activity is intended by the DOE to remain small, no significant organizational changes are contemplated. Funding will be provided through the Nuclear Physics Program of DOE. Program decisions among competing proposals for use of the End Station A facilities for nuclear physics will be made with the advice of a separate committee that is expert in that field and which reports to SLAC's Associate Director, Research Division. We note that there are considerable uncertainties in forecasting the total demand for this new nuclear physics facility during this projection period. There is a sharp increase of interest within

the nuclear physics community in high energy electron scattering on nuclei. The interest is accentuated by the proposed construction of a 4 GEV, unity-duty-cycle electron accelerator dedicated to nuclear physics research elsewhere in the United States. Since the time of construction of that facility would span the entire period of this projection, it is possible that the growing community intending to use the new facility may on an interim basis generate intense demands on the much more limited, low-duty-cycle facility at SLAC. However, since the total time available on this facility remains limited, we are not projecting any larger expansion of the nuclear physics program throughout this projection period.

IV. SCIENTIFIC PROGRAM AT SLAC

Particle Physics at SLAC

The Particle Physics Program at SLAC is based on four accelerator facilities. These are:

1. The two-mile linac, which is used for fixed-target experiments and the production of test beams.
2. The 200-meter circumference SPEAR storage ring, which is used for experimental studies of electron-positron collisions up to 7.4 GeV in the center-of-mass.
3. The 2.3-km circumference PEP storage ring, which is used for experimental studies of electron-positron collisions up to 35 GeV in the center-of-mass.
4. The SLAC Linear Collider (SLC), which will be used for electron-positron annihilation experiments up to 100 GeV in the center-of-mass.

The linac is the oldest of the SLAC accelerator facilities. Experimental operation began in 1966 at an energy of about 16 GeV. The maximum energy capability of the linac has increase over the years and is now 32 GeV. As part of the SLC construction project the maximum energy of the linac will be increased to 50 GeV. The linac is not heavily used for particle physics experiments at the present time. The presently accessible energy region has been well explored, and while there are still specialized high energy physics experiments that use it (about one per year), its primary function is to supply test beams for apparatus development and to serve us an injector into our storage rings. Recently a new injector has been added to the linac at about the 80 percent point, and with this new injector high-intensity, low energy beams can be obtained for use in nuclear structure experiments. The linac program may become more active when 50 GeV beams are available.

The SPEAR storage ring began operation in 1972 with a maximum center-of-mass energy of 5 GeV. It was soon upgraded to allow it to reach energies of 7.4 GeV and has recently been further improved to increase the maximum available luminosity. Half of the running time of a SPEAR storage ring is devoted to high-intensity single electron beams for the production of x-rays to be used by the SSRL program.

The PEP storage ring began operation in 1980 and currently serves five major experiments. Its maximum center-of-mass energy is 35 GeV, but operations have been concentrated at 29 GeV, its maximum luminosity point, since its turnon. Design studies are underway to make a significant improvement in the luminosity of this machine. A single beam port to allow synchrotron radiation studies on a parasitic basis will be available begining in 1986.

The SLAC Linear Collider (SLC) is a new type of colliding-beam facility. The linear collider technique appears to have the potential to be extended in future machines to very much higher energies at considerably lower cost than the storage ring technique which has been used up to now for electron-positron colliding-beam studies. The SLC will be completed at the end of 1986, and we expect experimental use to begin in the spring of 1987. The experimental program will initially concentrate on studies of the Z^0 region.

In Section A below we discuss the physics associated with the Z^0 energy range to be studied using the SLAC Linear Collider. Sections B and C review, respectively, the physics associated with the PEP and SPEAR energy ranges. In Section D we look ahead briefly to the physics that could be done with electron-positron linear colliders in the TeV energy range. We do this because the desire to develop the accelerator technology to reach this energy is part of the motivation of building the SLC, and is the impetus for other accelerator physics research at SLAC.

In Section E we describe a potential particle-physics program that would use the direct electron beam and fixed targets, and the nuclear-physics program

that uses a new injector in addition to existing fixed-target facilities. Finally, in Section F, we briefly describe the activities of the Theoretical Physics Group at SLAC.

A. Physics with the SLAC Linear Collider

The SLAC Linear Collider (SLC) will operate at center-of-mass energies up to 100 GeV; this energy could eventually be increased to about 140 GeV should the prospective physics so warrant. In this section we describe the main areas of physics interest that the linear collider could address.

(1) The Z^0 and Its Decay Modes. The principal goal of SLC physics is the detailed study of the Z^0 vector boson, the neutral carrier of the weak interactions. The existence of the Z^0 has recently been established in an experiment at the CERN $\bar{p}p$ collider, and its mass is close to the predicted value of ~ 95 GeV/c^2. It is expected that the Z^0 will be copiously produced in e^+e^- annihilation. Indeed, the yield of multihadron events should exhibit an enormous peak at the Z^0 resonance. The hadron/electromagnetic muon-pair ratio R is expected to increase from a value around 5 at present energies to about 3000 at the Z^0 mass.

The Z^0 is expected to decay into pairs of all the fundamental leptons and quarks whose masses are less than 1/2 that of the Z^0:

$$e^+e^- \to Z^0 \to e^+e^-,\ \mu^+\mu^-,\ \tau^+\tau^-,\ \nu_e\bar{\nu}_e,\ \nu_\mu\bar{\nu}_\mu,\ \nu_\tau\bar{\nu}_\tau,\ \ldots$$

$$\to Z^0 \to u\bar{u},\ d\bar{d},\ s\bar{s},\ c\bar{c},\ b\bar{b},\ \ldots$$

Each cross section is proportional to $(V_f^2 + A_f^2)$, where V_f and A_f are the vector and axial-vector coupling constants for the $Z^0 - f - \bar{f}$ vertex, and where f represents any of the fundamental fermions. In the Weinberg-Salam model $(V_f^2 + A_f^2)$ is of order one, so that all the cross sections are roughly proportional to the available phase space. The resulting large sample of all these decays allows detailed studies including the measurement of branching fractions and the angular distributions of the charge asymmetry. Deviations from the predicted universality

among the three generations of quarks and leptons would point to a problem in the standard model. Polarization-related parameters will serve to separate the V_f and A_f coupling constants.

(2) Electroweak Interactions at Energies Beyond the Z^0. The behavior of cross sections and the measurements of weak-electromagnetic interference in the interesting regions beyond the Z^0 will be an important test of the ideas that predict unification of these two forces. In addition, the energies above the Z^0 may offer the best promise for studying new phenomena not seen in Z^0 decays.

(3) Hadronic Processes. The Z^0 is a prolific source of quark-pairs of all flavors that are not too massive to be energetically excluded. Decays of the Z^0 into quark-antiquark pairs of different flavors will be seen through fragmentation into collimated jets of hadrons. The multihadron decays should be a particularly good source of gluon jets radiated from the primary quarks, and should allow a thorough study of the QCD properties of quarks and gluons. Although some QCD predictions will be tested at lower energy machines, extension of these measurements to higher energies will be an important test of QCD ideas. For example, scaling violations in fragmentation functions and broadening in 3-jet events should be pronounced at these higher energies.

(4) New Phenomena. An often considered and controversial aspect of SU(2) $\times$ U(1) is the Higgs boson. The conjectured boson (or bosons) is responsible for the origin of mass in the standard model, and understanding its properties could lead to a fundamentally important understanding of the mass spectrum of particles. If light enough, Higgs bosons could be seen in the decays of the Z^0 to the Higgs and lepton pairs, for example.

There are already hints at CERN of unexplained physics in the Z^0 region consisting of events with a high energy photon and large missing energy, and "monojet" events with unbalanced transverse momentum. Such unusual events of appropriate energy could be easier to study in the quantity and with the clarity characteristic of an electron-positron collider.

Free quarks are often discussed as a possible final state at the higher energies. Heavy leptons, neutral as well as charged, or any new particles that carry weak charge, may also exist in the final states. Electron-positron annihilation is the most promising method to search for such dramatic events. The most important discoveries may well come from a list of effects which today are only speculations or are unknown.

(5) Polarization Studies. Neutral-current processes are expected to exhibit large polarization-dependent effects. Annihilation of longitudinal polarized electrons on unpolarized positrons in the collider will permit the investigation of the full set of spin-dependent effects and allow very accurate measurements of many neutral-current parameters.

Intense beams of longitudinal polarized electrons can be made available at SLAC, and the SLC is designed to preserve the polarization. Linac beams with polarizations of 50% have already been used, and beams of higher polarization are a good future prospect.

Polarization asymmetries complement the branching ratios and charge-asymmetry measurements for the different lepton and quark types. The accuracy of $\sin^2\theta_W$ should immediately improve an order-of-magnitude over present low energy measurements in the early SLC data, and the polarization information will contribute significantly to this improvement. As data accumulate and specific decays of the Z^0 can be isolated, measurement of the vector and axial vector coupling constants for the different quarks and leptons should provide a stringent test of $SU(2) \times U(1)$ ideas.

B. Particle Physics Using PEP

PEP is designed for center-of-mass energies in the range from about 8 GeV to 36 GeV. As described in Section VI, the luminosity of PEP is excellent, and plans are now being formulated for improving the luminosity to even higher levels. A very broad range of physics is now being carried out at PEP, and we can only briefly summarize that physics here. Experiments at PEP and PETRA have

begun to explore this broad range of physics, but there is much more work to be done. The physics we summarize below is not only that now being done at PEP but is also the physics that will be available in future years.

(1) Hadronic Physics. This topic itself divides up into several areas that are being intensively pursued at PEP.

(a) General hadronic physics: There is a large class of topics that do not require the partition of the multihadron events into two-or-three jet events. These include the study of particle yields of K's, $\bar{p}$'s, Λ^o's, D's, etc. Some of this work has already been done at PEP and PETRA, but increased statistics are necessary to permit studies which go beyond simple particle-yield cross sections. There is strong interest in the mechanics of the hadronization process. In particular, the study of long- and short-range charge and flavor correlations is being pursued. Here one is asking whether charge and/or flavor are conserved locally within a jet (as in the case of all simulation programs), or whether the conservation is achieved globally. The $K^{\pm}$'s, K^o_s's, Λ^o's, $\bar{p}$'s and D's are particularly useful for flavor studies, while for charge correlations all charged tracks can be used. Another example of ongoing work is the question of how baryons are produced in the hadronization chain. What hyperons are produced? Are decuplet baryons suppressed? Are baryons emitted "first" in the chain, or in a statistical manner? Is baryon number conserved locally or globally? Studies are also continuing in longitudinal- and transverse-momentum structure of heavy flavor jets.

(b) Three-jet physics: While there have been many studies of three-jet events at PEP and PETRA there is a great need for much more data in order to understand the physics of these events in detail and to test the theory of quantum chromodynamics (QCD) in model-independent ways. It is also necessary to develop model-independent methods to measure α_s and to study second-order perturbative corrections. For example, the study of one effect of second-order corrections, namely four-jet events, is still in its infancy.

Large data sets can be used to distinguish between string models and inde-

pendent fragmentation models.

(c) Quark and gluon jet discrimination: There is the important question of whether gluon jets can be distinguished from quark jets. If this can be done one wants to study separately the properties of each type of jet. This involves the use of the three-jet events and the study of the multiplicity, particle yields (flavor), and $\langle p_T \rangle \langle p_L \rangle$ for each jet. Statistically the softest jet is 50% gluon-rich according to QCD folklore. This is a crucial issue for testing the gluon self-coupling.

(d) Single photons and jets: Photons can be produced directly in hadronic final states by either initial-state radiation or final-state radiation. Events of the type $q\bar{q}\gamma$, where the γ is radiated from one of the quarks, produce 3-jet events where the third jet is just one photon and is thus easily measured. By measuring the gamma energy spectrum and angular distribution, one can use these events to probe the final state fragmentation and test for factorization.

(2) Physics with Secondary Vertex Detection. Two detectors at PEP, MAC and HRS, now have secondary vertex detectors. (The Mark II, which was the first to use such a device, has removed their system in order to test other components in its upgrading program for the collider.) Their programs divide naturally into two parts. The first concentrates on well-defined measurements, namely the τ lifetime, the D^o lifetime, and the B-meson lifetime. These are briefly discussed below. The second part of this program, which is more exploratory, includes searching for events with separated vertices, developing a charm and bottom tag by looking for tracks with large transverse momenta, and hunting for invariant mass bumps in events with displaced vertices.

(a) Precision measurement of the τ lifetime: The τ lifetime has been previously determined to $\pm 17\%$ statistical error, confirming our understanding of the τ lepton as partaking in the conventional weak interactions in spite of its relatively large mass. Continuing studies should reduce this error to $\pm 5\%$, and correspondingly reduce the systematic uncertainties to about $\pm 5\%$. Note that this is the level at which universality "breaks down" in the quark sector, i.e.,

$\sin^2\theta_c \approx .05$.

(b) Other uses of secondary vertex detectors: As an example, consider the measurement of the impact parameters of leptons produced in semileptonic B and D decays. With appropriate cuts on the lepton's longitudinal and transverse momenta (with respect to the jet axis), the data divides into B-enhanced and D-enhanced samples. These tagged events permit the study of heavy quark lifetimes, fragmentation properties, and multiplicities. Three detectors at PEP have used this technique to measure the lifetime of the B-meson.

(3) Studies of B Meson Physics. Hadronic events containing leptons are very suitable for studying some properties of b quark production and decay. The excellent capability of the PEP detectors for identifying electrons and muons is yielding interesting results in several areas of B meson and b quark physics:

(a) Determination of the neutral weak coupling constants for b quarks: The e^+e^- interaction is most suitable for studying the coupling of c and b quarks to the Z^0. (Neutrino-induced neutral current reactions are better for u and d quarks.) Although the b quark production is small, the forward-backward asymmetry is expected to be relatively large. In the Weinberg-Salam theory, at 29 GeV, the asymmetry is predicted to be 18%. To carry out such a measurement one needs to determine the production angle of the quark and the quark flavor. The thrust or sphericity axis gives to a good approximation the production angle. Good identification of leptons yields a useful method for identifying the b quark through its semileptonic decay $b \to \ell\nu X$ and for determining which jet is quark and which jet is antiquark. We can expect asymmetry measurements with an error of about 7%. The vector coupling constant of b could also in principle be determined from the total production cross section. However, this is a more difficult task because QCD corrections of different orders contribute to that cross section. This work is in progress and needs more data.

(b) Weak mixing: Since the b quark decays with significant probability to the c quark, the semileptonic decay chain of b and c starting from a $b\bar{b}$ pair yields

multilepton events. The probability of obtaining two or more charged leptons depends on the ratio $\sin^2\beta/\sin^2\gamma$, where $\sin\beta$ measures the coupling strength in the $b \to u$ transition, and $\sin\gamma$ measures the ratio of the coupling strength of $b \to c$ compared to $t \to b$. Multilepton events lead to a measurement of this ratio and also provide information on $b\bar{b}$ mixing.

(c) Features of the fragmentation function of the b quark: PEP detectors have already obtained useful measurements of $D_b(Z)$, the fragmentation function of the b quark. They used the electron and muon momentum spectra. More extensive and better information will allow us to discriminate among different shapes for $D_b(Z)$, and thus to understand in detail how the b quark produces hadronic final states. Detailed comparisons of b-quark events with light-quark events probe the difference between the fragmentation of heavy and light quarks.

(4) Two-Photon Physics. The two-virtual-photon reactions

$$e^+ + e^- \to e^+ + e^- + \gamma_v + \gamma_v$$

$$\gamma_v + \gamma_v \to e^+e^- \quad , \quad \mu^+ + \mu^- \quad , \quad \tau^+ + \tau^- \quad , \quad \text{hadrons}$$

are attracting growing interest. The lepton-pair reactions offer new tests of QED and of the point-particle nature and propagator of the τ.

The reaction leading to hadron production allows measurement of the total cross section $\sigma_{\gamma\gamma} \to$ hadrons, single-particle inclusive distributions, production of exclusive hadron pairs at high p_T, the production of hadron jets by photon-photon reactions, and the exclusive production of resonances. Deep-inelastic $\gamma e^\pm$ scattering can also be studied given a sufficiently large acceptance. These measurements provide tests of QCD. Most of the PEP detectors can study these processes to some extent, but the TPC/Two-Gamma experiment is optimal for this work.

The studies of hadronic final states cover a broad range of physics topics. One example is the search for two-photon production of states like the $\theta(1650)$ and

the $\iota(1440)$ that have been observed in the "glueball-favored" prompt-photon decay $J/\psi \to \gamma X$. Since the photon couples to charge, the two-photon production of a glueball state should be suppressed relative to the production of a $q\bar{q}$ state with similar mass and quantum numbers. Measurements of the $\gamma\gamma$-widths of pseudoscalars provide a sensitive test for their possible glueball content. A measurement of the $\gamma\gamma$-width of the η_c will provide a significant further constraint on models of the charmonium system. Other examples are the study of $\pi\pi\pi\pi$ and $KK\pi\pi$ production; a large production cross section at and above threshold can be interpreted as evidence for a 4-quark bound state.

(5) Studies of Charmed Particles at PEP. The study of the production of D mesons at PEP energies will continue. Mixing in the $D\bar{D}$ system is of interest. There is also the challenge of finding out how to study charmed baryon production in the PEP energy range; this is a very interesting subject because we do not yet understand the production of ordinary baryons in electron-positron collisions. The charm fragmentation function needs more study in the light of the HRS data on $D_c(Z)$ at low Z.

(6) Studies of τ Physics. Measurement at PEP of the τ single-charged-particle branching fraction yields $86 \pm 1\%$. Experiments at PETRA have confirmed this result. Yet adding up the measured single-charged-particle decay modes yields only about 75%. Tagged tau events can be used to study this significant disagreement. Several individual branching fractions are being measured at PEP where the errors are smaller than at SPEAR.

Measurements of Cabibbo-suppressed τ decays lead to a limit on the τ neutrino mass. Further study of Cabibbo-allowed multiprong decays may help resolve long-standing experimental disagreement about the A_1.

(7) Weak-Electromagnetic Interference Effects. Interferences between the one-photon-exchange and neutral-weak-current amplitudes occur in both dilepton and hadronic final states. These interference terms lead to observable effects of many types. For example, in the case of $e^+e^- \to \mu^+\mu^-$, weak-electromagnetic

interference will, in general, lead to a polar-angle distribution of the form

$$1 + \cos^2\theta - a\,s\cos\theta$$

where θ is the angle between the μ^+ and the e^+ beam.

Interference effects should also manifest themselves through asymmetries in high-momentum hadrons at a level comparable to those in the $\mu^+\mu^-$ case. A full study of asymmetries in high-momentum hadrons requires reliable identification of π's, K's and p's. The TPC/Two-Gamma experiment at PEP is particularly well suited for this purpose.

(8) Searches for New Particles. Electron-positron collisions offer a clear way to produce new particles through pair production

$$e^+ + e^- \to X + \bar{X}$$

Some examples of particles which may be produced within the PEP energy range are particles predicted by supersymmetric theories, Higgs particles, non-sequential heavy leptons, neutral heavy leptons, free quarks, hadro-leptons, and so forth. There have been a number of powerful and comprehensive searches for such particles at e^+e^- facilities, and an important part of the PEP program is carrying out such searches. The very large hadronic data set from PEP of 10^5 hadrons makes it possible to search for interesting effects down to the 10^{-4} level. We discuss three examples:

(a) Supersymmetric particles: Supersymmetry is a theory which introduces a new boson for every fermion and a new fermion for every boson. It also requires that the coupling strengths of these particles be the same as their normal partners except for spin factors. Some of these particles are expected to be light; examples are the photino and the Higgsino (spin 1/2 partners of the photon and Higgs boson). The remaining particles may be heavy, but if the lower limits for the

mass of these objects become too high, the theory fails to solve the mass hierarchy problem in standard theories. Scalar leptons and photinos can be produced and detected through the reaction $e^+ + e^- \rightarrow \tilde{\ell}^+ + \tilde{\ell}^-$, $\tilde{\ell}^- \rightarrow \ell^- + \tilde{\gamma}$. Another interesting way to produce and detect photinos is $e^+ + e^- \rightarrow \gamma + \tilde{\gamma} + \tilde{\gamma}$.

A new experiment at PEP, called ASP for Anomalous Single Photons, has been installed with these peculiar events as its main game. The MAC detector has added small-angle counters to give it sensitivity to some of these same events. Single photons also signal a radiative decay into two neutrinos, and these experiments bear on the question of the number of neutrino flavors.

(b) Neutral heavy leptons: There have been no comprehensive and definitive searches for neutral heavy leptons because the only known general method for producing them is

$$e^+ + e^- \rightarrow Z^0 \rightarrow L^o + \bar{L}^o$$

and that production cross section is small at PEP and PETRA energies. Ignoring threshold factors, $\sigma \sim 2 \times 10^{-37}$ cm^{-2}. However, with much improved luminosity at PEP, we will be able to carry out a significant search.

(c) Other searches: There are two types of events where it is interesting to look for new particles in a very general way: low-multiplicity events, and multilepton hadronic events. In both cases the major sources of these events are known processes. Low-multiplicity events come from pure electromagnetic processes, from τ-pair production and decay, and from beam-gas interactions. Multilepton hadronic events come from heavy quark production and decay. Large statistics studies will enable us to apply more severe criteria for seeking out new particles among these known processes.

C. Particle Physics Using SPEAR

SPEAR operates in the center-of-mass energy region up to 7.4 GeV. Since 1972, experimental work at SPEAR and at the similar German storage ring DORIS has established much of the fundamental physics in this energy region.

Since DORIS is now operating at higher energy, SPEAR now provides the only access to this important energy region.

The pioneering work at SPEAR includes the discoveries of the psi-particle family, charmed mesons, hadronic jets, and the tau lepton. The significance of this work is, to say the least, well-established. The present and future physics programs at SPEAR build upon these foundations and look into several open issues.

(1) The F-meson. The F-meson has been identified and its mass measured, but there remain questions about its weak decay branching ratios. A semileptonic decay study would allow the measurement of the F^+/D lifetime ratio.

(2) Charmed Baryons. Our knowledge of the charmed baryons is little better than that of the F mesons. Only a few decay modes of the Λ_c have been observed in e^+e^- studies, and data from other experiments have very low statistics. There is little data from e^+e^- studies or elsewhere on other charmed baryons, such as the Σ_c, which can be cleanly produced at higher SPEAR energies.

(3) Psi Family. Although we know a good deal about ψ and χ states of the charmonium family, there remains much more to be learned. An example comes from the Crystal Ball experiment at SPEAR, which demonstrated that the η_c state does exist, and that its mass is rather close to the ψ mass. The Mark III detector has since measured the spin and parity for the η_c ($J^P = 0^-$).

The radiative decay modes of the ψ are the best place to look for possible bound states of gluons, and the Mark III's accumulation of nearly three million such decays is turning up interesting structure.

The Mark III study of the ψ'' system has improved the understanding of the D meson decay mechanism. New data will improve limits on $D\bar{D}$ mixing.

Strong interest in the ψ family comes from the theoretical expectation that the $c\bar{c}$ system can be studied in an approximately nonrelativistic framework, which means that it should be possible to study the quark-quark interaction in

this system in great detail.

(4) D Mesons. There are still many aspects of the physics of the D mesons that remain to be studied in detail and understood. These include the semileptonic decay modes of the D, particularly the Cabibbo-suppressed modes; the different lifetimes of $D^{\pm}$ and D^{o}; and the nonleptonic decay modes of higher multiplicity.

(5) The Tau Lepton. Two aspects of τ physics of great interest are better measurements of the multihadron decay modes of the τ, and a search for the decay process $F \rightarrow \tau + \nu$ and second-class currents such as $\tau \rightarrow B + \nu$.

(6) Total Hadronic Cross Section in the 4-5 GeV Region. This energy region exhibits a complex structure with at least three peaks. These peaks are thought to be related to higher mass states in the $c\bar{c}$ system, but this hypothesis has not been seriously tested. The physics of this region remains to be thoroughly explored. With sufficiently good measurements a further understanding of non-relativistic potential models of charmonium is possible.

(7) Total Hadronic Cross Section Above 5 GeV. Existing measurements of the hadronic cross section above 5 GeV are in crude agreement with the quark model, but detailed agreement cannot be obtained, even with full QCD corrections. Future SPEAR physics can explore whether this disagreement is attributable to measurement errors or to some fundamental error in the theory. Sufficiently good measurements of R can lead to an improved determination of α_s.

(8) The Unexpected. Finally, there may well be some new phenomena that remain to be discovered in the energy region between about 3 and 8 GeV. The region is so complex in structure that some of the contributing processes may not yet have been observed.

D. Physics of Electron-Positron Collisions in the TeV Region

One of the exciting aspects of the SLAC Linear Collider is that it will help

to develop the accelerator technology needed to build a yet higher energy linear collider. Other parts of the SLAC program in accelerator physics and technology are also directed to that goal. Therefore it is useful to present a brief sketch of the important physics that could be done with an electron-positron linear collider in the TeV region. For convenience we use the example of a collider with a total energy of 1 TeV. Such a facility offers four extraordinary ways to move into a new world of particle physics:

(1) Increase in Mass Scale. The mass range for searching for new particles will be extended a factor of five to ten over the mass range available to accelerators now under construction. (There are CERN's LEP, SLAC's SLC, Fermilab's TEV-I proton-antiproton facility, and UNK in the Soviet Union.) Examples of possible new particles are heavy leptons or heavy quarks so massive that they decay to W's and Z^0's. For example, a quark Q of several hundred GeV mass decays via $Q \rightarrow W + q$, where q is a less massive quark. One can look for heavy relatives of the Z^0 with masses up to 1 TeV, or for heavy charged Higgs particles pair produced via $e^+ + e^- \rightarrow H^+ + H^-$. Or if the Technicolor theory is correct, the Technicolor analog of the ρ, called ρ_T, can be copiously produced via $e^+ + e^- \rightarrow \rho_T$ up to a 1 TeV mass.

(2) Probing for Particle Structure. One of the outstanding problems of particle physics is whether the leptons and quarks are elementary or composite. If they are elementary, why are there so many different kinds? If they are made up of simpler particles, why have we not found any evidence for their being composite? The pair production of these fermions, $e^+ + e^- \rightarrow f + \bar{f}$, at very high energy offers the best hope of resolving the paradox. This is because the pair-production cross section can be precisely calculated if the fermions are elementary, but if they are composite we will see deviations from the calculated point cross section as well as other effects.

(3) Clear Signals and Relatively Small Backgrounds. Electron-positron physics in the 1 TeV region has the very valuable property that it offers a rela-

tively high ratio of the expected cross sections for known physics. This is because the known physics processes have distinctive signatures and can usually be identified. Hence they leave a rather small residual background against which the new physics must be observed and studied. This is in contrast to hadron-hadron collisions where the background from known physics will often overwhelm the search for new physics.

(4) Unexpected New Physics. Electron-positron physics is characterized by the simplicity of the initial state and by our ability to calculate precisely how that state is transformed through the electroweak interaction. Hence this physics offers the best opportunity to discover and interpret unexpected new physics at very high energies. The situation is much more difficult in hadron-hadron collisions, where the initial state is complex and the strong interactions play a crucial role.

The foregoing is just a brief sketch of the extraordinary particle physics that can be done with electron-positron collisions in the 1 TeV region.

E. Fixed-Target Physics at SLAC

(1) NPAS — Nuclear Physics at SLAC. NPAS is a program of nuclear-structure physics based on an intense electron beam of 0.5 to 6 GeV and the electron-scattering facilities at SLAC. A new injector (NPI for Nuclear Physics Injector) has been designed to inject electrons into the last six sectors of the linac to produce the required beam without requiring the use of the full linac length. This is significantly more efficient and also provides more flexibility for the SLAC program. The NPI is installed and running.

(a) Approved NPAS experiments: The NPAS program now includes three electron-scattering experiments which will use the spectrometer facilities of End Station A. One experiment will study backward scattering from deuterium at large momentum transfer. Two fixed-position spectrometers will be set up to detect the forward scattered electron and the backward recoil deuteron. Both elastic and inelastic scattering will be studied, with the backward kinematics

allowing a clean separation of the magnetic structure function. The experiment should be able to discriminate sharply among several theories.

The electroproduction of the delta isobar will be measured using a variety of targets and the 8 GeV and 1.6 GeV spectrometers. A Rosenbluth separation would provide the transverse part of the cross section. This experiment probes medium range nucleon interactions, which show up as a shift and broadening of the resonance.

Electron scattering from nuclei using the 8 GeV spectrometer and a variety of targets from hydrogen to gold concentrates on the high-momentum transfer region where quark dynamics might dominate and probes the high-momentum distribution of nucleon. The interest in quark processes in nuclear physics comes from the EMC effect observed at CERN and similar work at SLAC.

(b) Very light nuclei structure studies: Recently, a series of experiments at SLAC has measured the elastic form factor of ^2H at high momentum transfers. These experiments straddle the boundary between particle physics and nuclear-structure physics. They are crucial for the quark model of light nuclei, and they make a unique contribution to nuclear physics. Extensions of this program are clearly of interest to the nuclear physicist.

(2) Possible Particle Physics Experiments. The future program for fixed-target particle physics is less definite than that for e^+e^- physics for two reasons. First, the SLAC fixed-target program covers a collision-energy range that has already been well surveyed and that we therefore already know a great deal about. Because of this, the experimental program tends to be a step-by-step process, with each new experiment depending upon the results of a previous experiment. The second reason for the less definite nature of the future fixed-target experimental program is financial. The increasing priority given to the e^+e^- program, combined with overall financial pressures, (particularly the large cost of power associated with high repetition rate operation of the full linac) have decreased the support available for fixed-target experiments at SLAC well below

the available opportunities. This has prevented planning a comprehensive and broad future program. Indeed, the financial restrictions have discouraged many physicists from planning any future fixed-target experiments at SLAC.

In this section we outline two physics experiments that could use the End Station A facilities at SLAC. These depend on the fact that the SLAC machine remains the highest energy and intensity electron accelerator in the world. The proton accelerators at Fermilab and CERN can produce electron, positron, and photon beams of higher energy, but the intensities are very much less, and the beams have significantly larger inherent phase space.

(a) Unpolarized deep inelastic electron-proton scattering: Two types of experiments are worthwhile. One is a relatively accurate measurement of $R = \sigma_L/\sigma_T$. R is a fundamental parameter in the general quark-parton model, and it is a quantity which should be calculable in any specific theory such as QCD. The deep inelastic muon experiments at proton machines cannot make as accurate a measurement of R as could be achieved by experiments at SLAC.

Another very worthwhile type of deep inelastic experiment is an extension of $e-p$ and $e-d$ measurements to the 30 or 35 GeV energy range made available by SLED I or SLED II. This would provide an overlap with the $\mu-p$ and $\mu-d$ deep inelastic scattering measurements made at proton machines. This is important because most of the Bjorken scaling violation, a major argument for the validity of QCD, occurs in this energy and Q^2 range.

F. *Theoretical Physics*

The research of the Theoretical Physics Group covers a broad range of topics and is generally characterized by staying in close contact with the experimental program at SLAC and at other high energy research centers. Efforts are continuing to study applications of perturbative QCD to jet physics. Although QCD stands as our most appealing and practical theory for studying hadronic processes, more decisive tests of its validity are still needed. Among the important ongoing studies are the analyses of multi-jets in electron-positron annihi-

lation, in search of distinctive differences between gluon and quark jets, and of flavor and charge correlations of secondary particles. Work continues here on the applications of QCD to elementary processes such as electron-positron annihilation. In addition, systematic studies of the applications of QCD to more complex processes with initial hadrons, and especially to nuclear (as opposed to nucleon) processes, are being undertaken. This requires deeper understanding of the bound-state properties of the theory, which lie beyond the realm of perturbative calculations alone. The study of quark-gluon plasma and its possible application to relativistic nucleus-nucleus collisions is being pursued.

Supersymmetric field theories are being analyzed in efforts to achieve the grand unification of all the forces of nature within a finite and renormalizable field theory formalism. In addition to understanding basic properties of supersymmetry, there are many phenomenological questions that have to be addressed by building specific models to compare with data on the lifetime of hadrons (including proton decay), and on the observed particle spectra in a broken symmetry theory. Predictions are being made on experiments planned for PEP, SLC, and LEP energies. The inclusion of super gravity in supersymmetric models is also a topic under investigation, as is the appearance of magnetic monopoles in such theories. Attention is also being paid to the foundations of quantum mechanics and to the possibility of developing a finite-particle-number covariant scattering theory as a basis for elementary particle physics.

The formulation and study of gauge theories on lattices, and in terms of discrete variables more generally, is also being intensively studied, both numerically and analytically. Efficient new numerical methods and algorithms have been developed and are being extended for determining the low-lying states of gauge theories on the lattice. These techniques are also being applied to a variety of problems such as spin systems, lower dimensional electron systems, polymers, etc., in order to gain physical insight into their application to real systems.

Certain topological indices, used to characterize different sectors of field the-

ories, are being studied and related to physical quantities. The same techniques are being applied to study fractional charge and fermion number states in particle theories and condensed matter theories that possess monopoles or solitons.

Questions of the composite nature of quarks and their possible unification with leptons are also being studied, both from the point of view of fundamental properties of theory and in terms of the experimental implications of compositeness.

Much of the research in the SLAC Theory Group is motivated by the physical questions: What experiments at PEP energies and higher (SLC, Tevatron, and LEP) can provide decisive new clues about the predictions of supersymmetry, about the possible compositeness of quark and lepton, about new physics involving Higgs bosons, and about the supersymmetric particle families?

Detector Research and Development

SLAC continues to be a leader in developing experimental apparatus and techniques germane to particle physics. The End Station A spectrometers and the Mark I detector at SPEAR are examples of detection facilities with which major discoveries were made. Indeed, the Mark I detector became the prototype for most colliding-beam detectors built since. Other examples of innovation from the past include the streamer chamber, the hybrid facility based on the rapid-cycling 40-inch bubble chamber, and the multiparticle spectrometer facility, LASS. Examples of the present interests of the laboratory are improved drift chambers of unparalleled tracking accuracy, (particularly vertex chambers) planar spark counters exhibiting the best time resolutions obtainable, Čerenkov ring-imaging detectors for high-momentum particle identification, and main-frame computer emulators to enable rapid analysis of the experimental data. We describe some of these examples in the following sections.

A. Drift Chambers

SLAC continues to advance the state of the art in track-chamber design. The Mark I spark chamber was the first large cylindrical chamber to be used for storage ring physics. The Mark II drift chamber gave considerably improved resolution in large tracking systems and was also the first of its kind. The many imitators of this concept attest to its success. More recently the Mark II tracking system has been augmented by a high precision vertex drift chamber to resolve, with excellent spatial precision, particle tracks close to the interaction point of the colliding electron and positron beams. The achieved precision of 80 μm has allowed the experimenters to measure the very short track lengths of such particles as tau leptons and charmed mesons.

New Mark II Drift Chamber. A new drift chamber is presently under construction for the Mark II Upgrade for the SLC. The general considerations for the design of the new chamber were as follows: good momentum resolution in the existing 5 kG magnetic field, good solid-angle coverage, ease of pattern recognition and high tracking efficiency at the Z^0, and dE/dx measurement as an independent aid to calorimetry for electron-hadron separation for momenta less than about 10 GeV/c. An average resolution of 150 μm and a dE/dx resolution of 4.7% have been achieved in the prototype.

Vertex Chamber Development. The Mark II collaboration is presently developing a high pressure drift chamber for use as a vertex detector at the SLC. The physics environment at Z^0 energies simultaneously demands high spatial resolution ($\sigma \leq 40$ μm per measurement is the goal) and excellent track-pair separation capability (≤ 500 μm). A prototype chamber has been constructed to extremely high mechanical tolerances for use in pressurized gases. The chamber incorporates a focusing grid structure which separates a uniform drift region from the amplification region. Resolution tests are underway. The SLC chamber is in its initial design phase, with a full length prototype due by mid 1985.

The MAC detector collaboration has also developed a new vertex chamber for its apparatus. This chamber consists of 324 wires strung through aluminized mylar straws between plates attached to a beryllium beam pipe at a minimum distance from the beam of about two inches. An active shield of bismuth germanate crystals was installed in the very forward region in order to provide shielding to the chamber without compromising its ability to work down to very small angles. The new vertex chamber has been in operation for some months. A preliminary estimate of the resolution is about 70 microns; somewhat better results are expected as the calibration procedures are refined.

Drift Chamber Studies for the SLD. Prototype chambers are being studied for the second SLC detector, the SLD. A cylindrical central tracker, somewhat smaller in radius than the Mark II chamber, will obtain higher resolution through improved electrostatics and use of different gas, CO_2-Isobutane (92%-8%). Localization of ionization from tracks will be done by waveform sampling chips and fast processors. The waveform sampling chips have been developed at the Stanford Integrated Circuits Laboratory and are designed for drift chamber signals. Tests of these chips are underway. Software code is being developed that will convert the drift chamber pulses into times and pulse heights. Multihit capabilities are possible within this hardware/software scheme. Beam tests using electrons and pions from 5 to 15 GeV/c are underway to provide a data base for the software development.

B. Čerenkov Ring Imaging Detectors (CRID)

When a particle travels through an optical medium, it may, depending on its velocity, produce Čerenkov light in a unique cone. In the past, Čerenkov detectors have been used in high energy physics to detect the presence or absence of light and thereby to tell whether the velocity was above or below the Čerenkov threshold. A new technique has been under development at CERN and at SLAC to take advantage of the unique angle of the cone of light so that velocities can be measured over a broader range. This technique involves the detection of

individual photons in the cone in order to form an image of the Čerenkov light of an individual particle.

In recent years it has been demonstrated that the photons from Čerenkov light can be detected in a drift chamber by introducing a photoionizing gas into the chamber gas mixture. By replacing the chamber walls with windows transparent to ultraviolet light, one can use this detector to image the cone of Čerenkov light from the particle. The potential for making a large-area Čerenkov detector can be realized by using a time-projection type of drift chamber to drift the photoelectrons up to a meter. The availability of a photoionizing vapor (TMAE) which overlaps the ultraviolet transmission of readily-available synthetic quartz windows has also contributed to the possibility of a large area detector.

The photoelectrons that have been drifted are detected by a multiwire proportional chamber along one end of the imaging plane. The wire number in the array gives one coordinate, and the elapsed drift time gives the distance across the imaging plane. This scheme allows relatively few channels of electronics to read out a large area.

The choice and handling of the optical medium for producing the Čerenkov light is also important. Perfluoro-n-hexane liquid, C_6F_{14}, has been studied because it is a room-temperature liquid with a low index of refraction and high transparency to ultraviolet light in the region of sensitivity of the photoionizing vapor. Tests at SLAC and CERN have shown that the transparency is good and can be improved by recirculating the liquid through commercially available oxygen filters.

A demonstration CRID has been operated at SLAC using the C_6F_{14} liquid radiator and a 20 centimeter square drift detector. Ring images from 11 GeV/c pions have contained 10 to 20 detected photoelectrons per image. A second device is now being used to study the drifting of Čerenkov rings up to 80 centimeters.

The CRID device has been chosen for inclusion in the SLD detector at SLC because of the superior performance it will have over other techniques of measur-

ing particle velocities. Software simulations have shown that the technique would be superior even if the detector performance were to deteriorate. Software and hardware development will continue in order to determine optimal parameters for the full scale SLD device.

C. Spark Counter Development

With the successful fabrication and testing of a spark counter of length 120 cm, we are now extending the length of the counters under development to 3 meters. The construction of two of these larger counters is well underway. In addition, we have fabricated and are testing two counters with a smaller gap dimension of 100 μm. With the smaller spark gap, these counters are expected to give significantly better time resolution than those we have built to date. All counters now being built incorporate several important innovations, including grounded-cathode design, chromium-surface cathode, position sensing in the transverse dimension, printed-circuit stripline readout, ease of fabrication, and a calibration pulser port.

Our program calls for investigation of the limits of spark counter resolution using the smaller counters, including the effect on the counter operation of including either xenon (5%) or Freon 13B (0.1%), in the gas mixture, and of replacing the argon completely with xenon. For the 3-meter counters, we will measure the time and position resolution as a function of operating voltage, and as a function of position.

With the testing of these counters, the spark counter detector development program at SLAC will draw to a close. At the present time, there is modest interest in spark counters world-wide: in Japan (TOPAZ experiment at KEK), in the U.S.A. (kaon beam physics at BNL and muon beam physics at Fermilab), and in Germany (as an alternative to scintillation counters at HERA).

D. Computer Emulators

The now famous 168/E processor emulator developed at SLAC has been in production computation. A "farm" of 9 processors is channel attached to the

SLAC central IBM 3081K computer and provides a compute capacity of about one half of the 3081K's total capacity. All the production from raw data tapes to DST tapes for Experiment E135 at SLAC is being done on the farm. Because of its success, a new generation of emulators has now been developed. The 3081/E has an order of magnitude more memory, more of the IBM instruction set implemented, full REAL*8 precision, and execution speed of about 3 times that the 168/E. The simple architecture and interfacing will be retained from the 168/E system. The program is being pursued in cooperation with CERN, and the first prototype processors are running at both SLAC and CERN. We expect the general production 3081/E processors to be installed during 1985.

Accelerator Research and Development

A. *Introduction*

Accelerator Research and Development at SLAC includes work on the storage rings SPEAR and PEP, the SLC linear collider, and other future colliders. The work on the storage rings is covered in other sections of this plan. In this section we present the R & D on the SLC and future colliders.

B. *SLC Upgrades*

The following programs to upgrade the SLC are presently being undertaken or studied. The SLC offers the possibility of colliding polarized electrons with unpolarized positrons. To accomplish this, it will be necessary to develop a high-current polarized electron gun. Work is in progress on a laser-driven photoemitter. It will also be necessary to install superconducting solenoids to control the spin direction of the electron beam on injection and extraction from the electron damping ring. Since there is rapid spin precession in the collider arcs, the strength of the solenoids must be variable over a considerable range. The optics of the damping-ring-to-linac beam transfer line must be consistent with the option of a variable solenoid strength.

The maximum number of electrons that can be accelerated in one SLC bunch is limited by the disruptive effect of transverse wake fields. A stronger quadrupole lattice would permit a factor-of-two increase in the current that could be accelerated. Such a lattice would contain approximately twice the number of quadrupoles and beam-position monitors as are presently installed.

The number of bunches accelerated in each pulse of the SLC could be doubled if improvements in the damping-ring kickers could be made. Each damping ring would contain double the number of bunches presently stored.

It might be possible to lower the effective beta value at the final focus. Stronger final-focus quadrupoles and an improved optical design would be required. Operating experience with the initial installation will be helpful in the preparation of a new design.

The energy of the SLC can be increased (in principle to 70 GeV/beam) either by increasing the power output of the present SLC klystrons or by adding klystrons and modulators to the accelerator. An improvement to the SLED energy-storage system could increase the energy of the SLC without increasing the klystron output power.

C. Advanced Accelerator R & D

Advanced accelerator R & D at SLAC is directed primarily toward the eventual realization of high energy, high-gradient linear electron-positron colliders. Such colliders fall into two general categories: far-future machines with energies on the order of 10 TeV and accelerating gradients exceeding 1 GeV/m, and nearer future machines with energies on the order of 1 TeV and accelerating gradients limited by the breakdown field in conventional copper accelerating structures. This breakdown gradient could be as high as several hundred MeV/m for short rf pulse lengths (several hundred nanoseconds) and higher rf frequencies (5-10 GHz) than those used in the present SLAC linac. The accelerating gradient for an optimized machine might, of course, be well below the breakdown limit.

1. Far-Future Linear Colliders. A number of acceleration mechanisms which might give gradients greater than 1 GeV/m have been proposed in recent years. Preliminary studies at SLAC and elsewhere have shown advantages and disadvantages for each concept. At present three concepts seem worthy of further pursuit: the laser-driven plasma droplet accelerator (a grating accelerator using disposable liquid droplets as a structure), the laser-driven plasma beat-wave accelerator, and the plasma wake-field accelerator driven by electron bunches. At SLAC we have chosen to focus our efforts on the latter two ideas. At the moment, work in these two areas is mainly confined to theoretical studies, although in the future there may be an experimental program or at least a collaboration in experiments at other laboratories. SLAC accelerator theorists will of course continue to follow developments in any area which might be applicable to high-gradient acceleration for linear colliders, and will be prepared to contribute where appropriate to the study and development of promising concepts which may be as yet unforseen.

2. Near-Future Collider Studies. A linear collider with an energy on the order of 1 TeV and a luminosity in the range 10^{32}-10^{33} $cm^{-2}sec^{-1}$ can probably be realized using only moderate extrapolations of present-day technology. There are two general approaches to such a machine: a conventional rf-driven linac, and a wake-field accelerator driven by high-current electron bunches. At DESY a prototype accelerator based on the wake-field accelerator mechanism is now under construction. Progress on this project will be watched with great interest, but at SLAC no experimental work on this type of machine is contemplated at present. We expect instead to concentrate our efforts on those areas of research which are necessary for the realization of a high-gradient collider driven by high-peak-power rf sources. Some areas of current effort are the following:

(a) Parameter studies: Choice of optimum parameters for a machine of a given energy and luminosity; choice of accelerating gradient and rf wavelength for minimum cost.

(b) Structure design: Optimization of structure geometry taking into account accelerating gradient, breakdown field limit at metal surfaces, and longitudinal and transverse wake potentials.

(c) Beam dynamics: Energy spread due to single-bunch beam loading; emittance growth due to alignment tolerances and to magnet jitter from ground motion; amelioration of transverse wake-field effects using Landau damping.

(d) Injection: Design of damping rings for minimum emittance.

(e) RF sources: R & D on the necessary high-peak-power rf sources to drive a linear collider (see below).

(f) Final focus: Design of a beam-transport system to produce the required sub-micron spot sizes at the interaction point, possibly for flat beams with large aspect ratios.

(g) Beam-beam effects: Simulation of beamstrahlung and disruption in high-current colliding bunches.

A group at SLAC (about 15 people) meets regularly to discuss and work on various problems related to the theory and design of very high energy linear colliders. The effort of this group is focused on conceptual and parametric studies of a linear collider of 1 TeV (each beam) with a luminosity on the order of 10^{33} $cm^{-2}sec^{-1}$. The group also studies excursions of these parameters to both lower and higher values. An important goal of this work is to explore the limits that can be attained with present-day technology, and to define parameter thresholds where new technologies will be required. From time to time, a benchmark study will be produced, focused on a specific set of collider design parameters.

In addition to the conceptual studies outlined above, some experimental efforts are now beginning at SLAC in several areas. As one example, impressive results have already been obtained in measuring the rf breakdown limits in conventional diskloaded copper accelerating structures. An accelerating gradient on the order of 100 MV/m has already been obtained at 2856 MHz with a pulse

ngth of 1 μs without breakdown. These measurements will be extended to igher field levels and possibly to a higher frequency in the range 5-10 GHz. In ddition, an effort is just beginning to measure dc breakdown limitations. Those mits are relevant to the design of the high power "lasertron" rf source described elow.

Even a cursory examination of the rf power requirements for a high-gradient ollider shows that very high peak power rf sources are needed. For example, o attain a gradient of 100 MV/m at an rf wavelength of 5 cm requires a peak ower of about 200 MW/m. If the number of rf sources is to be held to a easonable total, the peak power per source must be several times greater. This ower should ideally be produced with high conversion efficiency. One possible ource that can meet these requirements is the lasertron, a device in which a odulated laser beam is used to produce bunched emission from a photocathode. n rf cavity is used to extract the energy of the bunches with high efficiency. n additional attractive feature of the lasertron is that it can operate directly om a dc power supply without the usual complexity and cost of a high-power odulator. An experimental program is now underway to produce a 30-50 MW sertron prototype during the next two years.

Various pulse-compression methods can also be employed to produce a short ulse at high peak power from a long-pulse, low-peak-power source. At SLAC a heme has recently been invented for multiplying the peak power of a source by factor of 2, 4, 8 or more, with of course a consequent reduction in pulse width. uring the coming year a low-power laboratory model of such power multiplier ill be developed, and if the idea continues to look promising, a full high-power rototype will be tested.

In parallel with the above work on room-temperature accelerator structures nd rf storage cavities, the Advanced Accelerator R & D program also includes n ongoing study of rf superconducting cavities. This program was originally ocused on the investigation of multipactor and field emission in cavities operating

under CW regime, but in the last two years has evolved in a new direction. Through a series of innovative experiments, it has been discovered at SLAC that superconducting niobium cavities can sustain fields of up to 65-70 MV/m without breakdown if they are operated with a short ($\sim 2.5\ \mu$sec) rf pulse. This discovery has opened new possibilities for fundamental research in the field as well as for applications to accelerators. It will be pursued during the coming years with a series of new tests and materials.

The above program will be supported and complemented at SLAC by a strong numerical modeling effort in the areas of cavity and structure design, beam transport and microwave source development. The program MASK is particularly well suited for simulating the highly nonlinear properties of high-space-charge, relativistic beams in rf sources such as the lasertron.

After a period of exploratory conceptual and experimental work in the areas outlined above, the Advanced Accelerator R & D program has as a goal to build a length of prototype linac for the acceleration of single bunches of electrons at high gradients, powered by efficient high-peak-power sources. The exact length, gradient and rf frequency of this collider linac prototype remains to be chosen, but it should attain a minimum energy of 1 GeV with a gradient on the order of 100 MV/m.

PEP Storage Ring Program

A. The Present Program

PEP is presently operating at 29 GeV in the center-of-mass with high peak average luminosity. The best peak luminosity to date is 3.2×10^{31} cm^{-2}sec^{-1}, and the average integrated luminosity has regularly exceeded 1 picobarn^{-1}/day. The experiments had accumulated approximately 250 pb^{-1} worth of data at 29 GeV as of June 1984. The full complement of detectors includes the Mark II (SLAC, LBL, Harvard); MAC (Colorado, Northeastern, SLAC, Utah, Wisconsin); DELCO (CalTech, SLAC, Stanford); HRS (ANL, Indiana, LBL, Michigan,

Purdue, SLAC); TPC (John Hopkins, LBL, Tokoyo, UCLA, UCR, Yale); and 2 Gamma (Netherlands, UCLA, UCSB, UCSD). In 1984 the changes in this experimental setup have been an upgrade of the TPC solenoid from 5 kg to a superconducting coil at 15 kg, and replacement of the Monopole Search by a new experiment, ASP (SLAC, MIT, Washington).

B. Future Possibilities

The thrust of the physics program has been to accumulate one very large data sample at one energy, rather than to spread data-taking over an energy range already scanned at PETRA. The future program depends on the outcome of the analysis of these data and could include further large data sets at different energies. In planning for the future we have, therefore, kept several options open. Engineering and accelerator physics studies have been carried out to clarify the costs and expected performance at significantly higher energies; viz, 40 and 46 GeV in the center-of-mass. In addition, studies have been initiated in the use of superconducting and permanent-magnet quadrupoles inside the large detectors to further lower the beta functions and thus increase the luminosity ("microbeta"). A similar program at SPEAR, which involves only a single large detector, is giving valuable experience in the engineering and physics problems of these techniques.

Last year a committee of experimental and theoretical physicists identified possible future PEP-upgrade programs and prepared recommendations on priorities. After careful consideration of the physics prospects and technical possibilities, the committee concluded that unless a new threshold is observed within the energy range accessible to PEP, there is insufficient justification for the expense and effort involved with the energy upgrades. However, they were unanimous in recommending that a program of luminosity upgrades should be pursued, as this would improve the physics programs under study much more than an increase in center-of-mass energy.

We note here that the Mark II detector, presently at PEP, will be upgraded and moved to the new SLC machine in time for first operation in late 1986.

In addition, the DELCO, MAC and ASP programs may be complete by that time. This has opened the possibility for a new approach to lower beta optics, the mini-maxi scheme. By changing the symmetry of PEP from 6-fold to 3-fold we can have 3 symmetric mini-beta IR's, while the other three have very large beta functions. This alleviates the problem of chromatic correction and allows the mini-beta regions to be designed with conventional quadrupoles close to but still outside the detectors. This mini-maxi scheme is presently in the engineering design stage.

In addition, construction has begun on a synchrotron light facility at PEP. By late 1985 a high energy x-ray line, emanating from an undulator in a symmetry straight section, will be available in a new building outside the PEP shielding. x-ray energies up to about 20 keV with useful fluxes will then become available, thus opening up a new region for study.

SPEAR Storage Ring Program

The SPEAR storage ring can produce electron-positron collision at center-of-mass energies from 2 to 8 GeV, with peak luminosity of about 3×10^{31} $\mathrm{cm^{-2} sec^{-1}}$. By agreement between SLAC and the Stanford Synchrotron Radiation Laboratory (SSRL), the running time at SPEAR is divided equally between SLAC's high energy physics research and the broad program of studies carried out by SSRL's research community. We review briefly here the present particle-physics program and some possible future modifications to the SPEAR facility. We also include a short summary of SSRL's plans for its future facilities.

A. The Particle Physics Program

Particle-physics research in the SPEAR energy region is described elsewhere in this Plan. We note that the Crystal Ball detector has been moved to the DORIS storage ring at the DESY laboratory in Hamburg, Germany, after a very successful career at SPEAR. The Mark III detector was installed in the

west interaction region at SPEAR in the summer of 1981, and since that time has been engaged in productive experimentation. Much of the early work has been concerned with studies of the production and decay of D-meson pairs, with SPEAR operating at a collision energy of 3.77 GeV. The present program calls for the accumulation of more data at this energy, and also for running at the psi resonance energy of about 3.1 GeV.

The energy region from about 3 to 4.5 GeV is so rich that a great deal more work will be required to understand all the observed phenomena. Thus a productive program of studies can be visualized for the Mark III that extends throughout the period of this projected Plan. Later work will include studies of the tau lepton and of charmed baryons, as well as a definitive study of the charmed/strange F meson.

During 1984 a micro-beta system has been installed in SPEAR, which will increase the luminosity by a factor of 3 to 5. New quadrupoles have been installed close to the interaction points. This requires special compensation coils to isolate the magnetic field of the detector from the quadrupoles.

B. Future Possibilities

Mark III upgrade. Several relatively minor changes in the Mark III detector are being considered. These include a new vertex detector.

Upgraded or special detector for SPEAR. It is unlikely that the richness of e^+e^- physics in the SPEAR energy region will be exhausted by the middle of the decade. We foresee that in 1985 or 1986 it may be desirable to continue SPEAR physics using a substantially upgraded general-purpose detector or a special-purpose detector. The special-purpose detector might use a large-solid-angle Čerenkov counter to emphasize the physics of electrons and kaons in the final state; or it might use sodium-iodide counters to emphasize photon physics; or it might emphasize some aspect e^+e^- physics that is still unknown. It is possible that a detector from PEP might be refurbished for these purposes.

C. Synchrotron Radiation Programs

SPEAR provides radiation sources for the Stanford Synchrotron Radiation Laboratory, a DOE-funded laboratory operated by Stanford University. At the beginning of 1983 there were five beam lines operating, three originating in bending magnets and two in eight-pole wiggler magnets. In 1984 a sixth beam line became available, originating in a 54-pole variable-gap permanent-magnet wiggler. In the summer of 1983, two new straight sections became available for source development by the removal of the rf cavities occupying those straight sections. The full energy capability of the storage ring was maintained by powering the remaining two rf cavities with higher power klystrons. Additional beam line developments are being planned in collaboration with outside groups.

SSRL has received construction funds for several modifications to the SPEAR facility that will improve the utility of the storage ring as a synchrotron light source. These include lattice changes to reduce the emittance, new in-vacuum wigglers that will produce high-brightness radiation at 8 keV, and some changes intended to improve the positional stability of the beam.

The Fixed-Target Program

A. *Accelerator Capability*

The program for accelerator energy upgrading with SLED I and SLED II has already been described. The relevant linac beam parameters for fixed-target experiments are summarized below.

	Standard	SLED I	SLED II
Maximum Energy (GeV)	23	33	50
Pulse Width (μsec)	1.6	0.2	0.2
Repetition Rate (pulse/sec)	360	360	180
Intensity (e/pulse)	5×10^{11}	2×10^{11}	3×10^{11}

B. *Experimental Facilities*

1. <u>Present Status</u>

The SLAC machine remains the highest energy and intensity electron accelerator in the world. Although the Fermilab and CERN synchrotrons can produce electron and photon beams of greater energy, their intensity is very much less, and the beams have a significantly larger inherent phase space. Similar remarks apply to positron beams. The SLAC accelerator also provides longitudinally polarized electrons, and transverse as well as circularly polarized photons.

As a result of the SLED I program, the SLAC accelerator has achieved beam energies up to 33 GeV. The beams presently available for physics include electrons, positrons and photons to End Station A; positrons in test beam line 19; pions, electrons and muons in test beam line 6; pions, kaons and antiprotons in test beam line 21; and monoenergetic photons for tests in beam line 27.

SLAC can also provide high-quality muon and neutral-kaon beams. The muon beams at SLAC are cleaner (smaller halo) because they are derived directly from muon-pair production in a small target, rather than from pion decay. The neutral-kaon beams are much freer from neutron background.

2. Future Possibilities

(a) Polarized electrons. An aspect of SLAC physics of considerable interest is the use of very intense beams of polarized electrons to explore the interference between the weak and the electromagnetic interactions. The SLAC polarized source (PEGGY II) has operated with beam polarization up to 50% and with intensities equal to those of the full conventional linac beam. An earlier source (PEGGY I) achieved polarization approaching 100% but at intensities two orders of magnitude lower. Work is underway to improve the polarization of PEGGY II to above 80%.

The observation of parity violation due to EM-weak interference opens up a new field for investigation. It is worth noting that because of the extremely small asymmetry measured (a basic asymmetry of 2×10^{-4} with the current kinematic variables), the required statistical accuracy precludes conventional counting methods. Rather, the light corresponding to many events for each pulse

produced by Čerenkov radiation or by scintillation in a shower detector is integrated. This technique is also applicable with the reduced duty cycle of SLED beams.

(b) Muon beams. High-intensity muon beams with small halos will be available from the SLED I upgraded SLAC accelerator at momenta up to 25 GeV/c. The muon-pair production mechanism carries with it the advantage that contaminating pions can readily be removed by interaction, so that pion/muon ratios of less than 10^{-2} are relatively easy to achieve. These parameters make it possible to extend the studies of hadron states produced in elastic lepton scattering to large effective masses, W. Previous studies have shown that for $W < 2$ GeV, inelastic lepton scattering shows no particular distinguishing structure in these final states. But this is unlikely to remain the case for the higher multiplicity, larger W events that can be reached with SLED energies.

(c) Nuclear physics at SLAC. NPAS is a program of nuclear structure experiments at SLAC funded by the Department of Energy within the U.S. nuclear physics program. It is based on the availability of an intense electron beam in the energy range 0.5 to approximately 6 GeV. This beam is produced using an off-axis electron gun and in-line injector, the Nuclear Physics Injector (NPI), installed at a point 6 sectors from the downstream end of the SLAC linac. The maximum intensity of this beam is larger than that available from the full 30 sector linac when operated in the energy range below 6 GeV due to the decreased effects of beam breakup in the shorter accelerator. The nuclear structure measurements are carried out using the facilities of SLAC End Station A.

The NPAS program is administered by the Associate Director, SLAC Research Division, with the assistance of the NPAS Coordinator. A Nuclear Program Advisory Committee (NPAC) is primarily responsible for program decisions. The Chairman of the NPAC advises the Associate Director of program decisions, and the Associate Director has final power of approval. The NPAS program is open to competitive proposals from all qualified experimenters. The

nuclear structure experiments are carried out within the financial constraints of the NPAS budget, and within the constraints of SLAC's resources and operating schedule.

V. Laboratory Resources

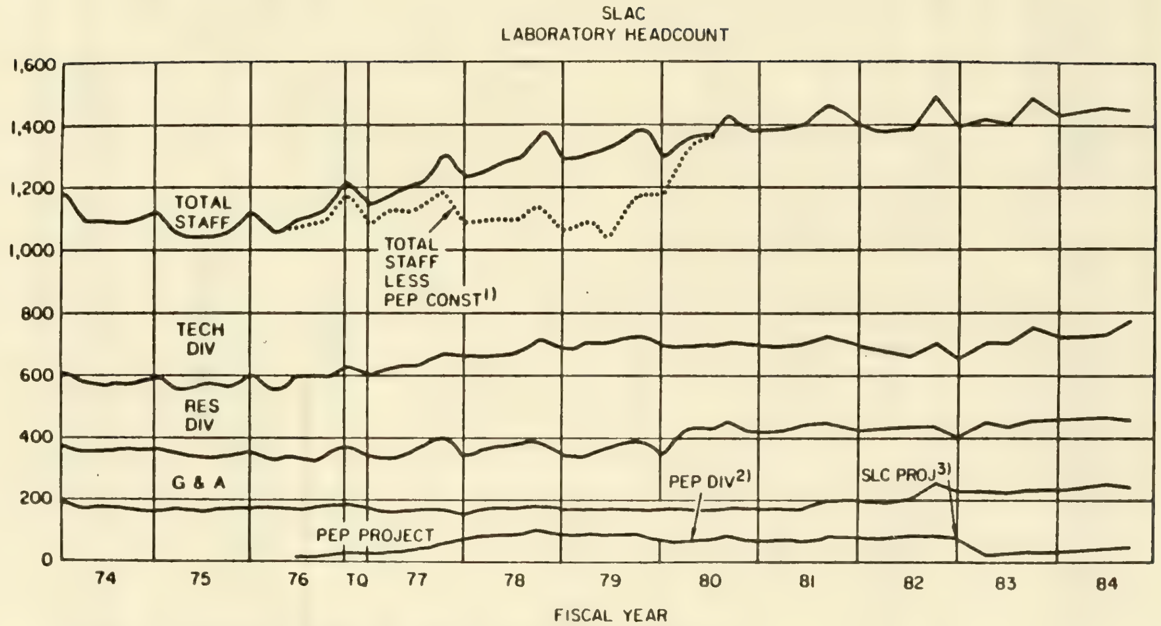
A. Personnel Resources

(1)Historical Pattern. Figure V-1 shows the employment pattern at SLAC since FY1974. This figure shows the tail end of a steady decline in staff corresponding to a period of declining resources in the first half of the 1970's. Since that time there has been a gradual increase to the present staffing level. The growth in staff through FY1982 is attributable to the effort involved in the construction of the PEP storage ring and its experimental facilities, and to their ongoing operation. The total staff increase required by PEP was approximately 235 people distributed between the Technical and Research divisions. These people are presently involved either directly in the operation of the PEP ring, or indirectly in facility-support roles. The continuation of the gradual growth trend through FY1984 (and beyond) reflects the construction needs of the SLC and its experimental facilities.

Figure V-2 shows the mix among blue-collar, clerical and professional staff at SLAC during the period from FY1978 through the middle of FY1984. As shown, the ratio of blue-collar to professional staff has remained roughly constant. However, Figure V-2 also indicates that the number of outside user residents at SLAC has grown from approximately 60 to 190 during this same period. As a result, there has been some reduction in the level of support services that can be provided to both in-house and outside experimental groups. Most notable is the lack of space (especially office and light lab space) to properly house our resident population. More on this in the next section.

(2) Projected Staffing Plans. Consistent with the recommendations of SLAC's Scientific Policy Committee, the number of SLAC and other Stanford University experimental physicists will be permitted to increase from the current number of 65 full-time equivalents to about 75 by FY1986 (the total number of individuals involved will approach 100). At the same time, a survey of the experimental

Figure V-1



1) Includes PEP construction and preconstruction R&D by SLAC forces (excludes LBL effort of a similar nature)

2) PEP project designation formally changed to PEP division 1/80

10-84 3) PEP division dissolved & reformed as SLC project established 10/82

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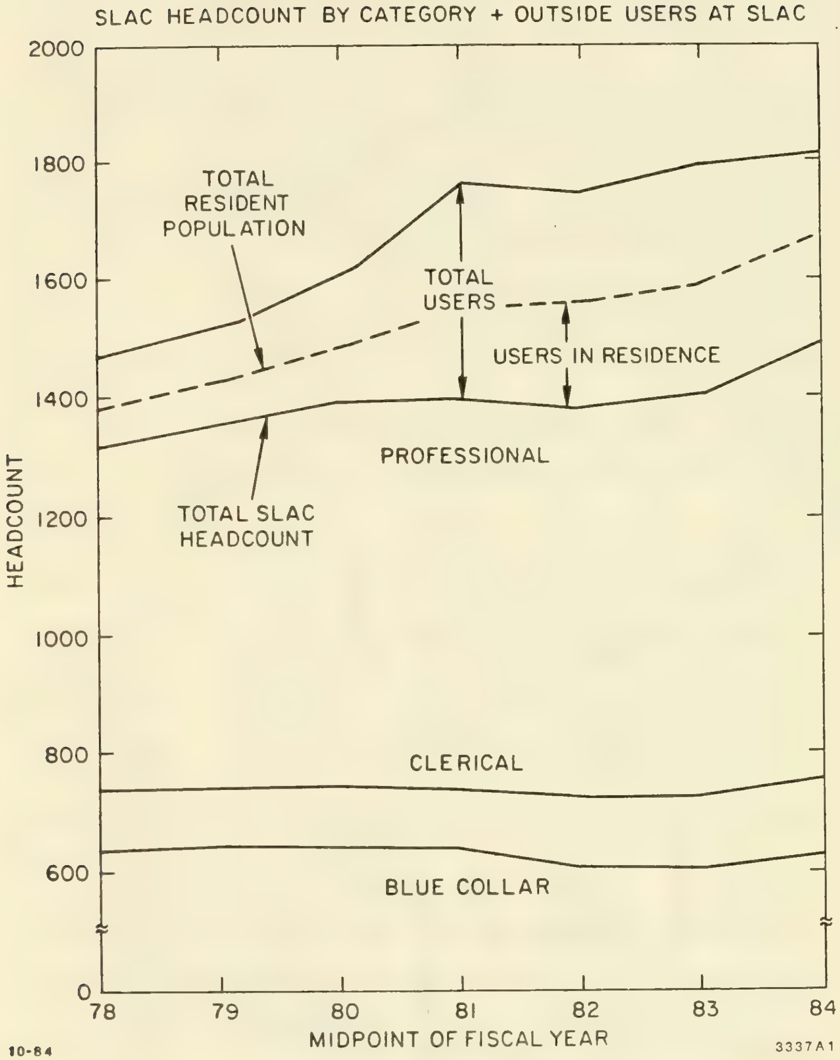
Figure V-2



SLAC HEADCOUNT BY CATEGORY + OUTSIDE USERS AT SLAC
2000
1800
1600
1400
1200
1000
800
600
0
HEADCOUNT
TOTAL RESIDENT POPULATION
TOTAL USERS
USERS IN RESIDENCE
PROFESSIONAL
TOTAL SLAC HEADCOUNT
CLERICAL
BLUE COLLAR
78
79
80
81
82
83
84
MIDPOINT OF FISCAL YEAR
10-84
3337A1

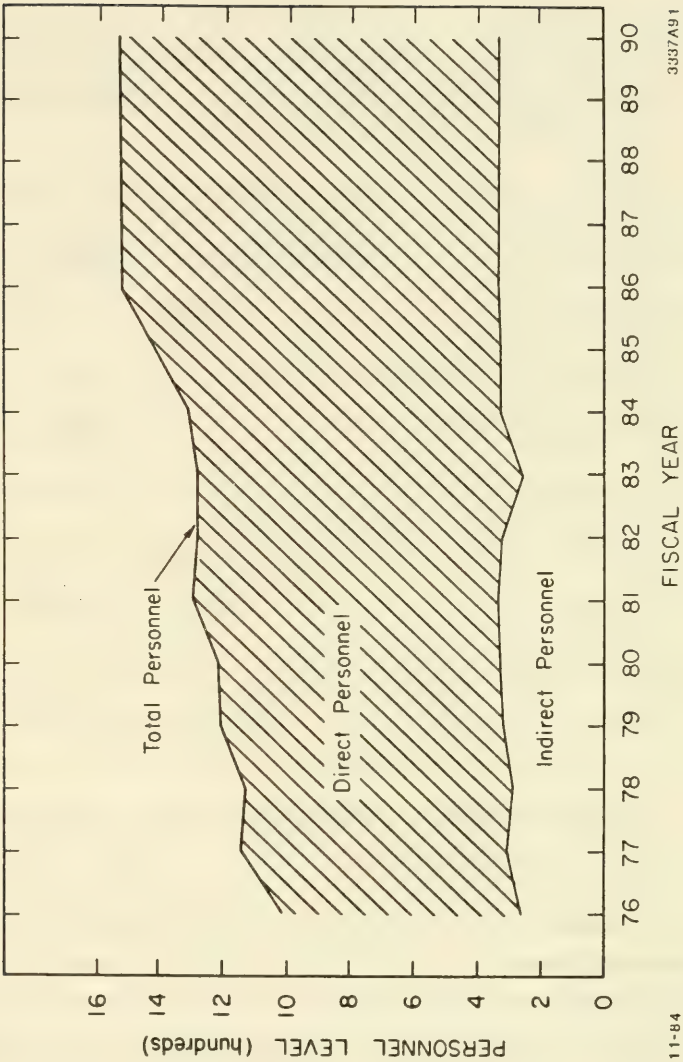
opportunities and needs in FY1986 indicates that a total of about 580 experimentalists will be active at SLAC. Of these, 75 possibly will come from foreign countries. We anticipate that this increase in user population will intensify our already severe space and other support problems.

Given the totality of the programs supported at SLAC, we anticipate that our total regular personnel will grow by about 6-7% by the end of FY1986 and level off afterwards. Figure V-3 shows the personnel requirements for the technical program through FY1990. Included in this personnel growth are engineers, designers, technicians, buyers, contract administrators, etc. There will also be a temporary increase in shop staffing during this period in order to meet the requirements of in-house fabrication of certain technical components of the SLC; the actual size of this increase will depend upon the outcome of the many "make or buy" decisions that are being made for the various SLC components. We will adjust this growth so that it matches our total needs after completion of the SLC. We expect to accommodate the peak personnel load during the construction period through a combination of temporary employees and subcontracts. Further additions to the total staff are not expected at the beginning of SLC operation in FY1987. SLC operations will be integrated into the present linac/storage ring control system, and facilities support for SLC experiments is expected to come from a reduction in the requirements of the fixed-target physics program.

(3) Personnel Recruiting. Besides the additional personnel requirements for the SLC project, it is also necessary to recruit due to normal turnover at a level consistent with that experienced over the past several years. SLAC is located at the northern end of the "Silicon Valley" which is home to numerous high technology companies. Because of SLAC's proximity to these companies, stiff competition is anticipated in obtaining the high quality staff demanded by the Laboratory's programs; some technical disciplines will be especially difficult to fill. Those that are identified at this time are technicians, electronic and electrical engineers, and computer programmers.

Figure V-3

SLAC PERSONNEL
(In FTE's)



(4) Professional Staff. Of the roughly 720 full-time professional employees, about 28% have bachelor degrees, 17% have masters or some professional degree, and 25% hold doctorates. Figure V-4 shows the distribution of years since baccalaureate and years since the highest degree received by the full-time permanent professional employees. Among the doctorates, who are mostly physicists, over a third received their doctorates less than ten years ago.

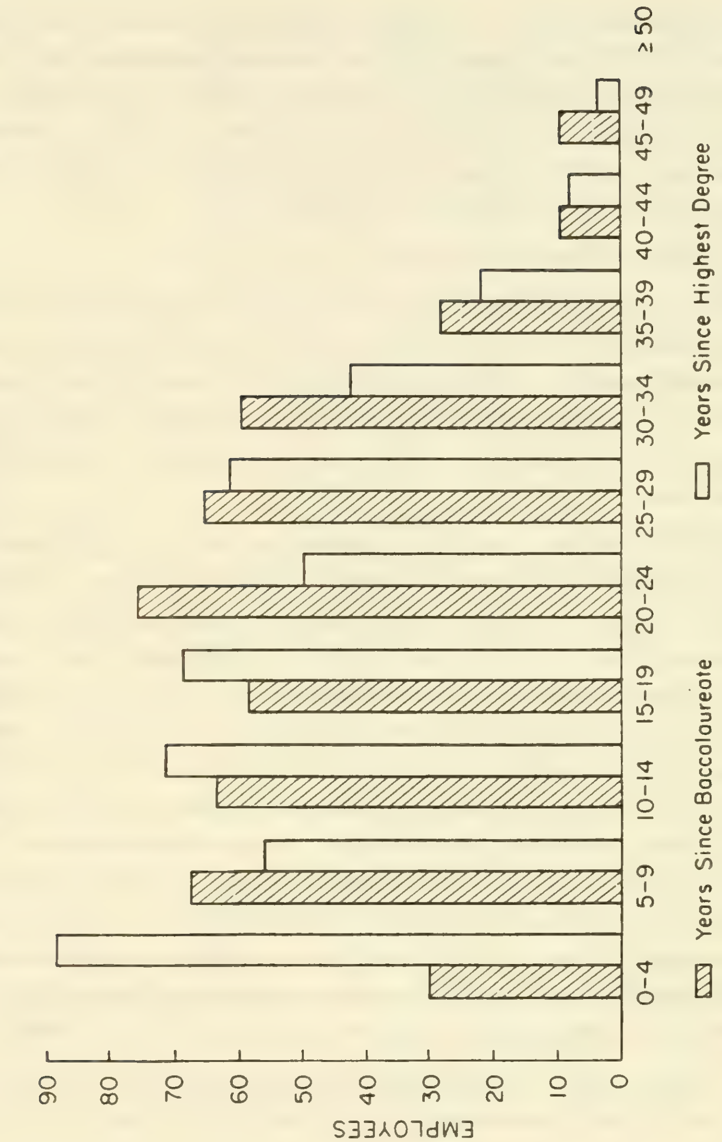
B. Overview of Space Requirements

The major space shortage at SLAC continues to be offices and light laboratories. These have been in chronic short supply for a number of years, and there are several known factors (described below) that are expected to affect this requirement over the period of this plan. Some of these changes have an immediate impact upon the laboratory, while others are contingent upon one or more future developments.

As PEP operation began the requirements for office and light laboratory space projected into the 1980's considerably exceeded the capacity of existing facilities. Use of the SLAC facilities in earlier years was characterized by an approximately equal balance between inside and outside users. Now, however, with nationwide focus on SLC and PEP, and with the reduction of the number of large high energy physics laboratories in the U.S., SLAC has experienced a growth in in-house staff and user "colonies". The trend is very pronounced with groups, for example, from LBL, the mid-west universities, several branches of the University of California, the Netherlands, Japan and the People's Republic of China. This has already resulted in more than a doubling of the outside user population in residence at the laboratory since FY1979. This increase in outside users exceeds the capacity of existing facilities. In addition, some provision must be made to house those engineers, designers, and technicians who are located in "PEP City". Additional office and light laboratory space is greatly needed.

(1) Office Space. The in-residence user population at SLAC has now grown to a level of about 190 and is expected to remain approximately level at that

PROFESSIONAL STAFF EXPERIENCE 1/



1/ Includes only full-time permanent employees with bachelor or higher degree

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number through FY1986. Our present user population is rather uncomfortably housed in an average of 55 net square feet per person, which is about one-half the space occupied by a regular employee. We would like to increase the average user-space allocation to approximately 90 net square feet. To do so will require the equivalent of 25 new offices.

SLAC's Central Laboratory and Central Laboratory Annex provide offices and light laboratories for most of the laboratory's experimental groups. As the number and size of experimental collaborations has increased, the overcrowding in these buildings has become acute. Currently, there are 325 office dwellers housed in 260 offices at an average of 88 square feet per person. To relieve this overcrowding will require an additional 65 offices.

The advent of the SLAC Linear Collider ultimately will add approximately 125 full-time employees to the SLAC staff, and much of that increment is already on site. Half of these employees require office space of some sort. To accommodate this growth SLAC will need an additional 35 office spaces and the user population growth attributable to the SLC will require an additional 20 offices.

Finally, we expect that SLAC will gradually augment its particle-physics staff by approximately 15 to 20 experimentalists in order to more adequately exploit the laboratory's increased physics potential. Each will require an office.

Presently, all permanent offices in the laboratory are occupied. Table V-1 summarizes the incremental office space needs of the laboratory over the period of this plan.

(2) Light Laboratory Space. The second area of chronic deficiency at SLAC is light laboratory space for both SLAC groups and outside users. The demand for light laboratory space, like the demand for offices, greatly increased as more outside users began experimental physics at PEP. Furthermore, SLC will add to light laboratory needs, as will the increased emphasis upon Advanced Acceleratory R & D and the advent of a viable program in Nuclear Physics. SLAC has a current inventory of approximately 20,500 square feet of light laboratory space,

Incremental Office Needs

Users presently in temporary facilities	20
User decompression	25
Users presently in the warehouse	57
Linear Collider users	20
SLC related staff growth	35
Addition of 20 physicists	20
Central Lab decompression	65
Net before PEP City removal	242
Remove PEP City	117
Total incremental SLAC office space need	359

Table V-1

and a projected need for an additonal 10,000 square feet. SLAC's space needs have grown quite acute, and it is imperative that more adequate facilities be provided to accommodate the enlarged physics community projected for SLAC. Since funding for facilities development within the high energy physics program has been severely limited over the past few years, SLAC has embarked on a series of General Plant projects to address this need. These projects are discussed below. Total space requirements are summarized in Table V-2.

(3) GPP. As discussed in section A above, space needs are a critical problem for the laboratory, and a line item construction project would be the most satisfactory solution to our foreseeable requirements. However, the space problem must be solved, with or without a line item construction project, and the assumption made here is that the solution will ultimately have to be substantially GPP-financed. There are, to be sure, other requirements extant within the laboratory which are appropriate for accomplishment with GPP funds, but the urgency of SLAC's space requirement has necessitated the deferral of some of this work.

Table V-2
Space Needs and Plans

	FY1985	FY1986	FY1987	FY1988	FY1989	FY1990	Total
Incremental Space Needs							
Central Lab Decompression	65						65
User Offices	122						122
SLC Growth	30	5					35
PEP City Removal	117						117
Physicists	5	5	5	5			20
Total Number of Offices	339	10	5	5	0	0	359
Gross Area Needed by Type							
Office	45,765	1,350	675	675			48,465
Light Laboratory	4,000	2,000	1,000	1,000	1,000	1,000	10,000
Drafting/Conference Room	5,000						5,000
Total Area Needed	54,765	3,350	1,675	1,675	1,000	1,000	63,465
Planned Additions							
Central Lab Modification	4,300						4,300
Central Lab 3rd Floor	9,600						9,600
Warehouse Conversion				20,000			20,000
General Services Building		6,000					6,000
Total Planned additons	13,900	6,000	0	20,000	0	0	39,900
Cumulative Space Surplus/(shortfall)	(40,865)	(38,215)	(39,890)	(21,565)	(22,565)	(23,565)	(23,565)

SLAC estimates that over the period of this report there will be a need for approximately 48,500 square feet of office space and 15,000 square feet of light laboratory, conference and drafting room space. This would be sufficient to house about 360 people, at a density of 135 gross square feet per person. To meet this need SLAC is currently planning to undertake a series of GP projects, spanning the period of this plan, that will include construction of new facilities and expansion/renovation of existing buildings. Projects included in this plan are:

(a) Central Laboratory Annex Fill-in. This project is currently under construction and will fill in an alcove in the Central Laboratory Annex created when the building was contructed around an existing tree which has since died. It will provide approximately 4,300 square feet of office and light laboratory space.

(b) Mezzanine Addition to General Services Building. This project would convert the General Services Building mezzanine to open area office space. It would provide approximately 6,000 square feet of office space.

(c) Third Floor Addition to the Central Laboratory Annex. This project would add a third floor to the Central Laboratory Annex. This 9,600 square foot additon would provide office space for about fifty people and would contribute, in conjuction with the previous items, toward a solution to SLAC's space requirements.

(d) Conversion of Existing Warehouse to Office/Light Laboratory Space. With the completion of SLC magnet production, the SLC magnet assembly facility will be converted to use as a warehouse. The present warehouse will then be upgraded to provide approximately 20,000 square feet of office/light laboratory space.

In addition to the space related GP projects, GPP funds will be utilized to upgrade support facilities consistent with programmatic needs and experimental objectives. Projected GPP requirements are summarized in Table V-3.

(4) AIP. During the period of this plan, the major items in SLAC's Accelerator Improvement Program are related to the use of the linac as an injector for the

Summary of Construction Budget
($ x 1,000 in FY1986 Dollars)

	Fiscal Year						
	84	85	86	87	88	89	90
Linear Collider	32,000	60,000	22,900				
AIP	1,875	3,785	2,800	2,965	2,965	2,965	2,965
GPP	1,285	1,695	1,700	1,780	1,780	1,780	1,780
Total	35,160	65,480	27,400	4,745	4,745	4,745	4,745

FY1984-FY1985 in then year dollars; FY1987-FY1990 in FY1986 dollars.

FY1986 funding from President's Budget.

Table V-3

SLC, and to full utilization of the SLED II mode of the linac. This program will upgrade the linac instrumentation and control (I & C) system and the radiofrequency and beam line components, through Sector 30, to handle highly confined beams. These improvements will result in real time computer monitoring and accelerator control of beam position and steering, and focusing and rf control of klystrons. In addition to the I & C improvements on the linac, new beam diagnostic instrumentation, to detect collider-type beams out of the accelerator, may be installed in the beam switchyard. Also planned is an upgrading of the pulsed magnet group in the front end of the switchyard. This work is for the purpose of deflecting collider energy into one or more beam switchyard transport systems. At least one major beam line will be upgraded to the 50 GeV level. Projected AIP funding required over the period of this plan is shown in Table V-3.

C. Central Computer Facilities

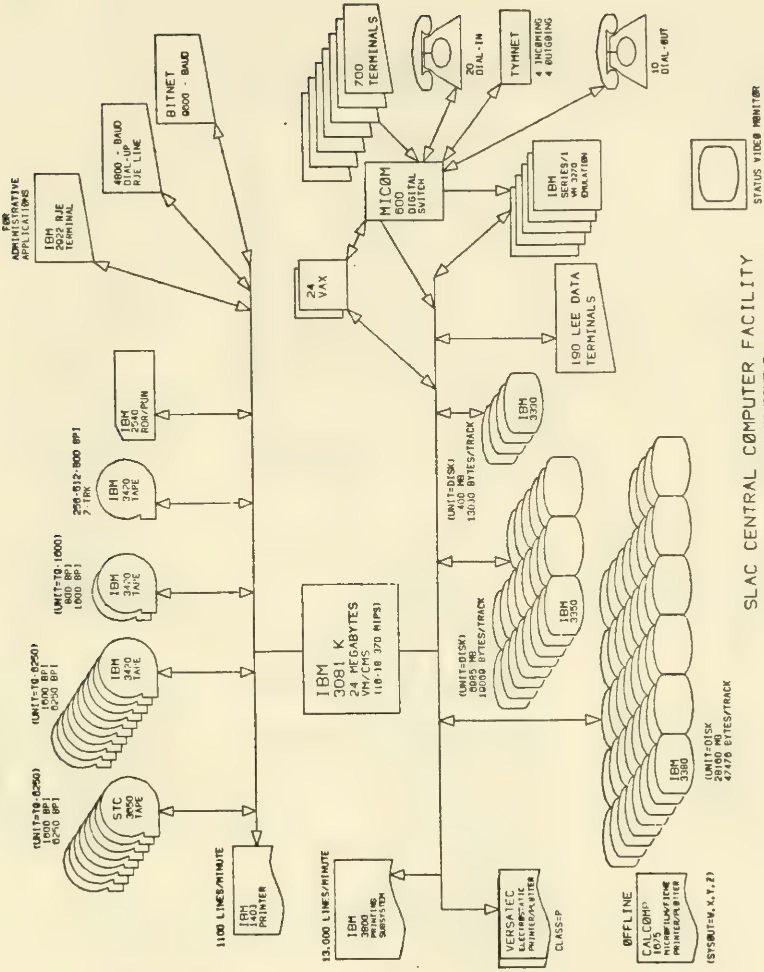
(1) Present Facilities. The SLAC central computer facility is based on an IBM 3081-K dyadic processor with 24 megabytes of main memory. It is connected to a large pool of disk space consisting of forty-four 3380 disk volumes, twenty-

two 3350 drives, and four 3330-1 units, providing a gross capacity of roughly thirty-five gigabytes of random-access storage. Other peripherals available to the processor include eighteen 1600/6250 bpi tape drives, three low-speed low-density tapes, and a Model 3800 page printer. A block diagram of this configuration is given in Figure V-5. The basic operating system is IBM VM/SP with slight modifications.

SLAC has a rather extensive on-site data communications network (illustrated in Figure V-6) which also provides some off-site access. Roughly 700 on-site ASCII terminals gain access to the central facility (through several front-ends) via a MICOM digital switch. These terminals can also dial out on the phone system, use TYMNET to connect to other sites, and connect to Fermilab computers through a leased line with statistical multiplexors. Off-site users also connect to the switch via dial-up or leased phone lines, commercial Tymnet service, microwave link from Lawrence Berkeley Laboratory or leased lines with statistical multiplexors. The switch then provides access to the central facility through two IBM 3705 front ends and five Series/1 systems providing full-screen emulation. There are approximately one hundred ninety 3278-equivalent terminals directly linked to five 3274-type controllers. In addition to the above, there is also an Ethernet, which provides terminal to computer connection and computer to computer connection.

(2) Expansion Plans. The planned major expansions are based on a forecast of computation requirements during the coming years. Figure V-7 shows SLAC's historical usage and installed capacity for the past several years. Our needs will increase by 50% by FY1988, primarily because of design and analysis activities associated with SLC. This will require upgrades to our present system as indicated below.

(a) FY1985 Upgrade. The upgrade of the IBM 3081-K to an IBM 3084, or equal, will provide about 24,000 NSU's (normalized service units) more capacity (i.e., 1.8 times a 3081-K) requiring no facility modifications and no new software.



SLAC CENTRAL COMPUTER FACILITY
USER-ORIENTED EQUIPMENT

Figure V-5

Figure V-6

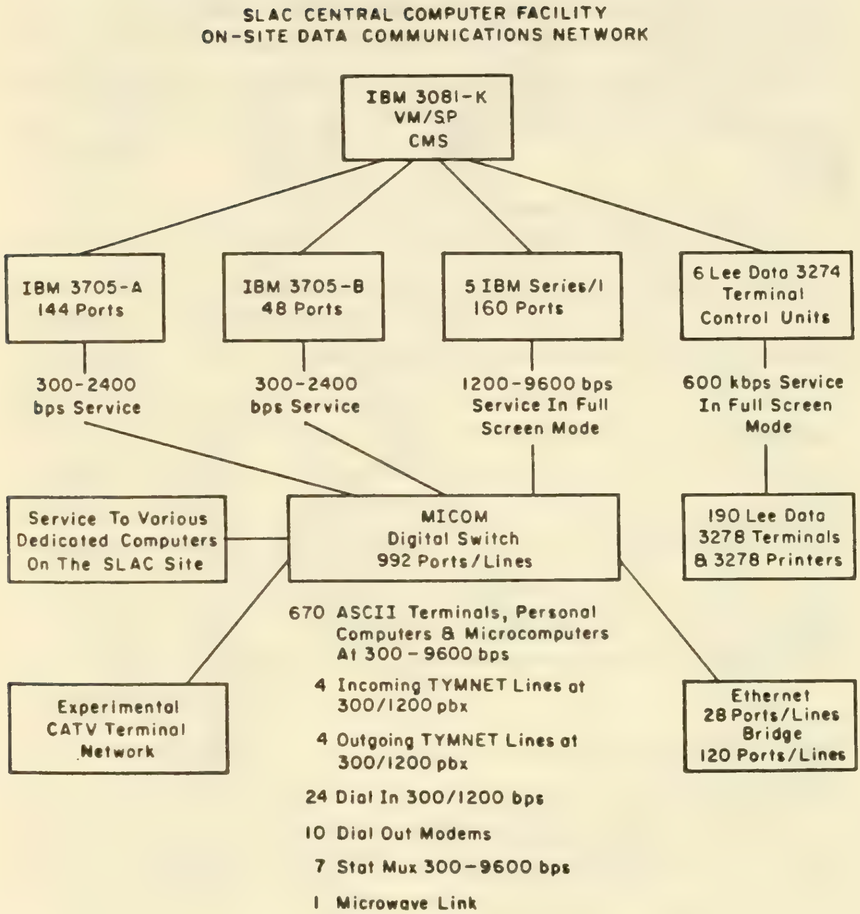
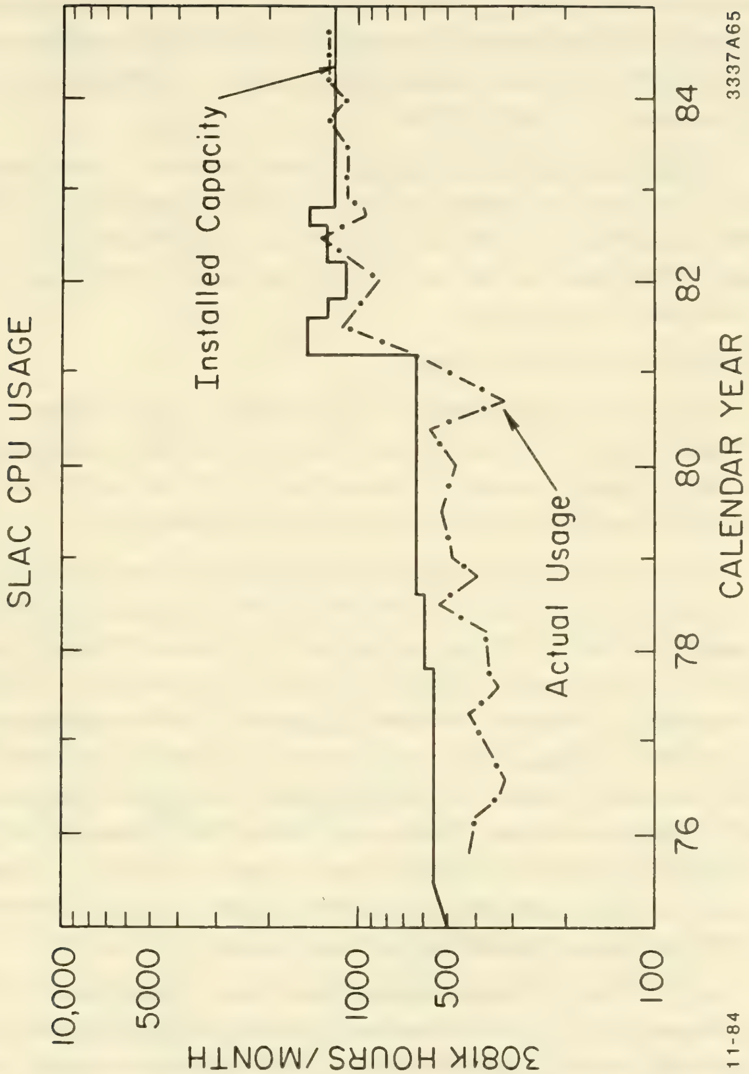

SLAC CENTRAL COMPUTER FACILITY
ON-SITE DATA COMMUNICATIONS NETWORK
IBM 3081-K
VM/SP
CMS
IBM 3705-A
144 Ports
IBM 3705-B
48 Ports
5 IBM Series/I
160 Ports
6 Lee Data 3274
Terminal
Control Units
300-2400
bps Service
300-2400
bps Service
1200-9600 bps
Service In Full
Screen Mode
600 kbps Service
In Full Screen
Mode
Service To Various
Dedicated Computers
On The SLAC Site
MICOM
Digital Switch
992 Ports/Lines
190 Lee Data
3278 Terminals
& 3278 Printers
670 ASCII Terminals, Personal
Computers & Microcomputers
At 300 - 9600 bps
4 Incoming TYMNET Lines at
300/1200 pbx
4 Outgoing TYMNET Lines at
300/1200 pbx
24 Dial In 300/1200 bps
10 Dial Out Modems
7 Stat Mux 300-9600 bps
1 Microwave Link
Experimental
CATV Terminal
Network
Ethernet
28 Ports/Lines
Bridge
120 Ports/Lines

Figure V-7


SLAC CPU USAGE
Installed Capacity
Actual Usage
3081K HOURS / MONTH
10,000
5000
1000
500
100
CALENDAR YEAR
76
78
80
82
84
11-84
3337A65

Prior to the acquisition of the 3084, or equal, a smaller computer will be required to provide additional capacity of approximately 5,200 NSU's. The upgrade would be a sole source procurement using purchase or lease-to-ownership since it would be an upgrade of an existing system.

(b) System Replacement in FY1988. A single system with upward compatible VM software and considerably faster disks will be acquired. The Model 3084, or equivalent, its contemporary peripherals and the smaller interim computer will be released at this time. This new system will provide a capacity of approximately 75,000 NSU's.

D. Energy Consumption and Costs

Table V-4 is a historical depiction of SLAC's energy sources and costs. Since electrical energy is the most important component of energy usage, this commodity is discussed separately in the next section. The section following that projects all energy consumption and costs at SLAC through 1990.

(1) Electrical Energy: Throughout its existence SLAC has received its electrical energy from two sources: the Western Area Power Administration (WAPA, formerly the Bureau of Reclamation) and the Pacific Gas and Electric Company (PG & E). WAPA energy is provided to SLAC in three components. The first component is an allocation of 25 MW of firm power. The second component is an allocation of withdrawable power which presently amounts to 14.3 MW. The third component is an allocation of diversity power which presently amounts to 6 MW. Therefore, at present (October, 1984) the total WAPA allocation to SLAC is 45.3 MW. The unit cost of WAPA power is currently 18.95 mills per kilowatt hour plus $ 3.75 per month for each kilowatt of peak demand. The history of WAPA rate changes from 1964 to the present is presented in Table V-5.

All SLAC electrical energy resulting from a power demand above 45.3 MW is obtained from PG & E at a rate that is presently 59 mills per kilowatt hour. The PG & E rate is a combination of two principal components: a basic energy charge that is presently 17 mills per kilowatt hour and a fuel adjustment charge

TABLE V-4

HISTORICAL ENERGY CONSUMPTION AND COST

Then Year Dollars in Thousands

	FY1976/ FY1976T	FY1977	FY1978	FY1979	FY1980	FY1981	FY1982	FY1983	FY1984
Electricity:									
GWH	233	206	210	174	192	268	240	283	227
Dollars	1,151	876	1,208	1,324	1,633	3,098	2,404	2,828	4,331
Shifts	740	588	669	658	727	709	688	769	570
Natural Gas (MGF)	63.3	52.9	55.1	54.5	50.7	48.1	44.4	48.2	46.0
Dollars	140.0	153.0	176.0	194.0	281.6	304.4	321.5	375.6	367.0
Propane (1,000 Gal.)	8.0	9.0	6.0	10.0	23.1	7.6	6.6	7.9	7.4
Dollars	2.8	3.5	2.5	4.2	11.4	4.8	4.5	6.3	6.1
Diesel (1,000 Gal.)	3.6	5.0	6.0	8.0	3.0	7.0	7.0	8.0	6.1
Dollars	2.0	3.0	4.8	8.8	3.4	8.0	7.0	12.8	6.1
Gasoline (1,000 Gal.)	32.2	29.7	33.5	39.6	39.2	37.1	36.4	36.2	30.2
Dollars	11.0	11.6	13.2	29.0	50.0	45.4	44.8	43.2	33.7

WAPA Rate Changes at SLAC

Date	Dollars/kW	mills/kWh
June 1, 1964 (See note 1)	$0.75	4.0, 3.0, 2.0 (See note 2)
April 1, 1974	$1.15	3.0
November 1, 1976	$0.75	4.0, 3.0, 2.0 (See note 2)
May 25, 1978 (See note 3)	$2.00	4.2
October 11, 1979	$2.00	5.11
May 25, 1983	$3.75	8.53
October 1, 1983	$3.75	13.74
October 1, 1984	$3.75	18.95 (See note 4)

Notes:

1. No contract from 6/1/64 to 2/10/65
2. First 130 kWh's @ 4 mills, next 130 kWh's @ 3 mills, and balance @ 2 mills
3. May 25, 1978 - Interim rate became effective to offset previous losses.
4. Increases are additionally proposed for:
   October 1985 - $3.75/kW; 27.97 mills/kWh
   October 1986 - $3.75/kW; 31.44 mills/kWh

Table V-5

that currently stands at 42 mills per kilowatt hour. The history of PG & E rate changes affecting SLAC is shown in Figure V-8.

Table V-6 shows SLAC's total electrical energy consumption and cost divided into WAPA and PG & E portions, by fiscal year since 1967. The last column of the table shows the average unit cost of total SLAC electrical power consump-

Table V-6

ELECTRICITY CONSUMPTION AND COSTS

YEAR	PEAK DEMAND (MW)	WAPA ALLOCATION (MW)	POWER CONSUMPTION (GWH)		POWER COSTS ($000)			Effective
			WAPA	PG&E	WAPA	PG&E	TOTAL	Mills/kWh
FY1968	38.0	25/35	171	17	703	105	808	4.3
FY1969	43.4	35/38/45	217	3	903	11	914	4.2
FY1970	51.6	45/40	208	7	884	34	918	4.3
FY1971	50.8	45/40	231	12	995	73	1028	4.2
FY1972	59.2	40	213	27	871	178	1049	4.4
FY1973	59.8	40/38	200	31	820	226	1046	4.5
FY1974	54.5	37.6	217	13	874	135	1009	4.4
FY1975	45.1	37.6	210	3	1028	37	1065	5.0
FY1976 (1	44.6	37.6	232	1	1125	26	1151	4.9
FY1977	46.5	38.2	202	4	785	91	876	4.3
FY1978	49.6	38.2/38.5	203	7	986	222	1208	5.8
FY1979	37.8	38.5	174	0	1324	0	1324	7.6
FY1980	44.2	38.75	192	0.1	1623	10	1633	8.5
FY1981	58.0	38.75	243	25	1955	1143	3098	11.6
FY1982	48.2	38.75	231	9	1875	529	1404	10.0
FY1983	53.1	45.3	278	5	2606	222	2828	10.0
FY1984	46.8	45.3	227	.1	4320	11	4331	19.1

Note: (1) data for FY1976 includes FY1976 T.

tion. Note that the average unit cost of electricity remained between 4 and 5 mills per kilowatt hour from FY1965 through FY1977. The cost then began to rise, reaching 19.1 mills per kilowatt hour in FY1984. Figure V-9 displays total electricity costs, and total electricity costs as a percent of SLAC operating costs.

It is interesting to calculate what the cost of electricity would have been if SLAC had found it necessary to purchase all its electrical energy from PG & E. For the period FY1973 through FY1984, during which PG & E rates have increased substantially, the additional cost would have been about $ 69 million. For FY1984 alone, the estimated additonal cost of PG & E power would have been about $ 9 million.

According to WAPA rules, any withdrawable-power customer whose load exceeds its firm power allocation at a time when the total WAPA system exceeds the maximum sustainable level is subject to a permanent loss of a portion of its withdrawable allocation. Over the years, SLAC has taken unusual care to avoid exceeding its firm allocation during these critical periods. As shown in Table V-7, during the years 1972-1984 there were 146 separate occasions on which SLAC reduced its total consumption to less than 25 MW. Because of the flexibility inherent in its experimental program, SLAC is prepared to continue such load reductions during future critical periods.

In addition to these "brownouts", SLAC has scheduled its non-operating periods in a manner that tends to minimize power consumption during critical summer periods and during the last half of December. Table V-7 also shows the scheduled downtime during these periods.

(2) Projection of Future energy Consumption and cost: Table V-8 presents projections through FY1990 of SLAC's consumption and costs for energy from all sources. The dramatic increase in power cost in FY1987 and beyond is caused by the demands of the SLC. In arriving at these numbers, we assume that all power beyond our present WAPA allocation comes at PG & E rates.

Table V-7

SLAC "BROWNOUTS" AND SCHEDULED DOWNTIMES

Year	Number of Brownouts	Months In Which Brownouts Occurred	Scheduled Downtime (Days)						
			May	June	July	Aug	Sept	Oct	Dec
1972	2	July	15	12	11	15	12	7	31
1973	6	July	8	13	5	31	5	17	31
1974	11	June, July	8	0	7	31	24	0	17
1975	10	June, July	0	0	5	31	30	7	8
1976	24	May, June, July	11	0	3	31	30	7	14
1977	8	June	0	4	31	31	30	7	13
1978	10	May, June, July	0	0	21	31	30	8	11
1979	12	May, June	0	1	30	31	30	21	10
1980	34	June, July, Sept, Oct (1) (17) (3) (3)	0	3	4	31	13	0	8
1981	13	June (13)	0	0	31	31	24	0	11
1982	6	May, June (3) (3)	0	15	31	31	30	7	4
1983	8	Jan, May, June (1) (4) (3)	0	0	31	31	30	0	10
1984(1	2	July, Sept (1) (1)	31	30	31	31	30	0	9
Total	146								

1) Both 1984 brownouts occurred during scheduled down months; limited load reductions were accomplished.

Figure V-8

PG&E RATE CHANGES AT SLAC

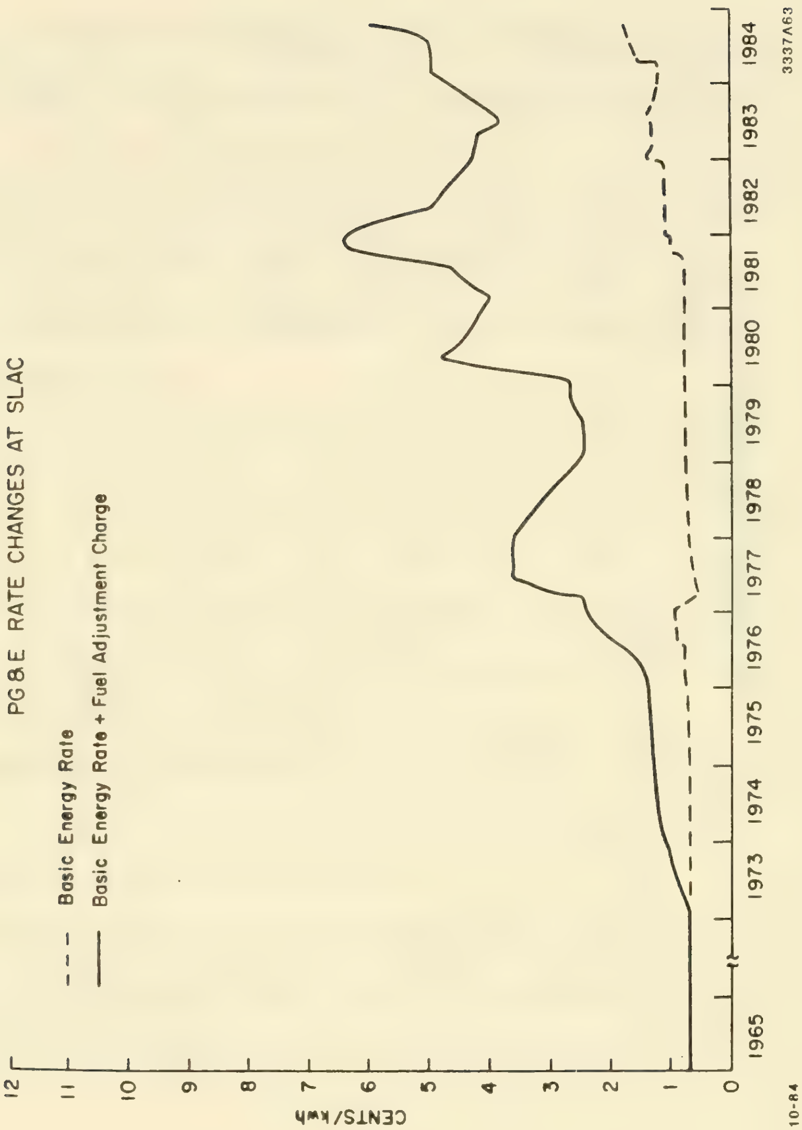


Figure V-9

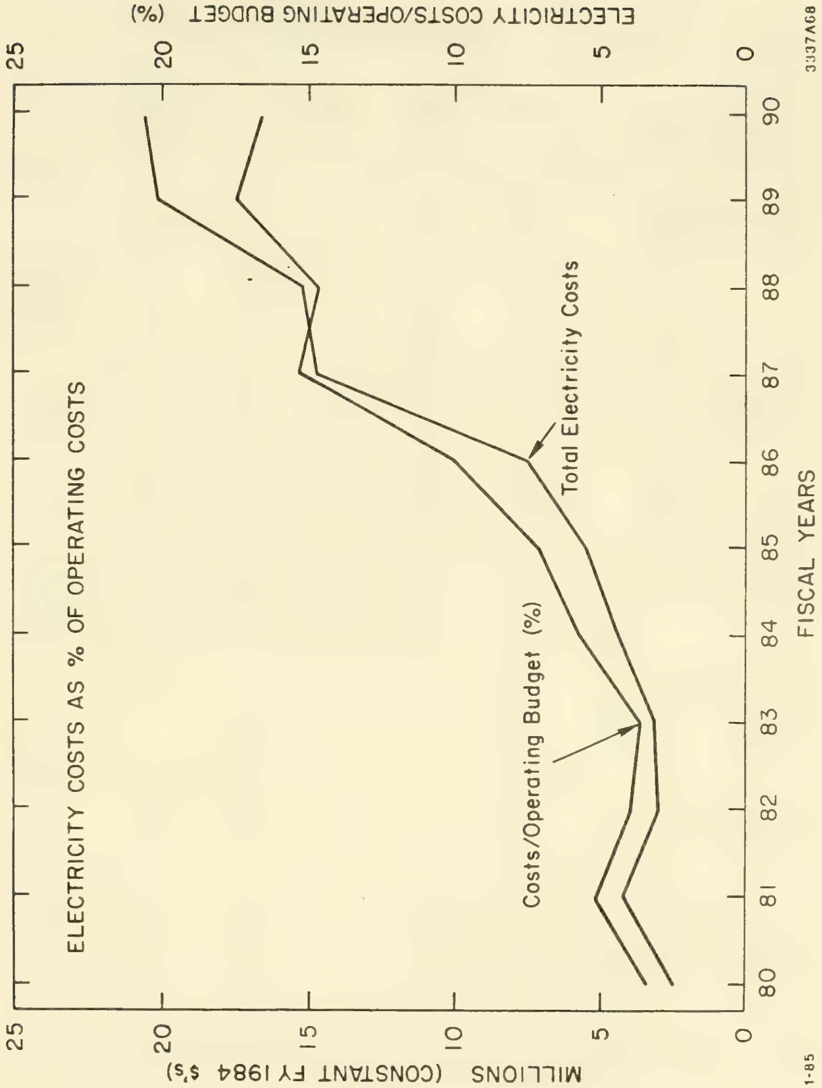

ELECTRICITY COSTS AS % OF OPERATING COSTS
ELECTRICITY COSTS/OPERATING BUDGET (%)
MILLIONS (CONSTANT FY 1984 $'s)
FISCAL YEARS
Total Electricity Costs
Costs/Operating Budget (%)
0
5
10
15
20
25
80
81
82
83
84
85
86
87
88
89
90
3337A68
1-85

Table V-8

PROJECTED ENERGY CONSUMPTION AND COST

	FY1984	FY1985	FY1986	FY1987	FY1988	FY1989	FY1990
Electricity (Costs in Millions of Then Year Dollars):							
30 Sector Linac							
No. of | 60 PPS	406	560	360	--	--	--	--
| 120 PPS	164	--	90	625	625	--	--
@ | 180 PPS			0	--		625	625
| # Shifts	570	560	450	625	625	625	625
Sub-Tot | Power Cost	4.3	5.3	7.0	17.7	19.3	27.5	30.2
| GWH	227	222	224	379	379	454	454
6 Sector (NPI)							
Shifts	--	140	180	180	180	180	180
Power Cost	--	0.2	0.4	0.6	0.7	0.8	0.8
GWH	--	9	12	17	17	17	17
Total Shifts	570	700	630	805	805	805	805
Total Power Cost	4.3	5.5	7.4	18.3	20.0	28.3	31.0
% e	15%	11%	15%	--	--	--	--
Natural Gas (MGF)	50	50	50	45	50	50	50
Cost (FY85 $'s X 1,000)	466	466	466	417	466	466	466
Propane (1,000 Gal.)	11	15	20	10	11	11	11
Cost (FY85 $'s X 1,000)	11	15	20	10	11	11	11
Diesel (1,000 Gal.)	9	9	9	8	8	8	8
Cost (FY85 $'s X 1,000)	11	11	11	10	10	11	11
Gasoline (1,000 Gal.)	35	35	35	30	35	35	35
Cost (FY85 $'s X 1,000)	50	50	50	42	50	50	50

Note: For power estimates, we have assumed a 45 MW WAPA allocation throughout.

E. Plant Maintenance

The basic philosophy in SLAC's site maintenance program has been to maintain the property in order to keep long-term operating costs low. In years when operations funding was insufficient, the laboratory elected to perform all essential maintenance and defer some of the non-critical items without impairing the safe operation of the laboratory. There is currently a small backlog of maintenance items which were funded in FY1984 but not completed due to scheduling. These items were not considered critical and did not result in any deterioration of the facilities.

The SLAC Plant Officer and his staff establish the routine maintenance schedule, periodically inspecting the buildings and grounds to identify necessary repairs and maintenance. All work is then prioritized and a work plan for each fiscal year is established according to the funding level.

Table V-9 provides the costs of the plant maintenance program planned for FY1985 through FY1990. Spending will be fairly level except for a small rise in FY1987 and FY1988 to provide paving of the roads to the klystron gallery. Roofing is the major item planned throughout the entire period.

Table V-9

SLAC FACILITY MAINTENANCE WORK PLAN

(FY 1985$'s x 1,000)

	FY1984~	FY1985~	FY1986*	FY1987	FY1988	FY1989	FY1990
Buildings & Grounds Maintenance							
General Building	$432	$691	$758	$758	$758	$758	$758
HVAC	455	490	538	538	538	538	538
Janitorial	475	535	587	587	587	587	587
Lighting	78	87	95	95	95	95	95
Lock & Key	42	16	18	18	18	18	18
Scavenger	51	47	52	52	52	52	52
Fire Alarm	87	122	134	134	134	134	134
Roads, Parking Lot	223	214	235	345	400	235	235
Landscape	177	166	182	182	182	182	182
Utilities Maintenance							
Electrical	249	249	273	273	273	273	273
Mechanical	249	249	273	273	273	273	273
TOTAL	$2,518	$2,866	$3,146	$3,256	$3,311	$3,146	$3,146

~In then year dollars
*Escalation factor:1.0976
FY1987 - FY1990 in constant FY1986 Dollars

VI. UNIVERSITY AND INDUSTRY INTERACTIONS

A. Extramural Experimenters

(1) Users: As SLAC completed its seventeenth full year of experimental research operations, the degree of outside user participation in the program continued at a high level.

During FY1984, a total of 45 outside institutions (31 U.S. and 14 foreign) participated in the SLAC experimental program. The distribution of experiments between outside users and in-house SLAC groups during FY1984 was similar to the general pattern that has characterized the SLAC program in the recent past. Roughly 85% of the beam hours in electronics experiments were utilized by outside users, about 65% of the SPEAR beam hours were utilized by outside users, and roughly 85% of the PEP running time was utilized by outside users.

Nationally, the total number of experimental physicists active in high energy physics continues to be constant at a level of approximately 1100, and we do not foresee either a large growth or shrinkage within this total during the period of this projection. Opportunities for high energy physics data collection in the U.S. continue to be divided among work at Brookhaven, Fermilab, Cornell and SLAC, in addition to minor activities not using accelerators. During the period covered by this plan there is some uncertainty about the long-range future of the work at Brookhaven. The work at Cornell involves a relatively small number of physicists.

The number of outside users at SLAC has grown from approximately 60 in FY1977 to approximately 190 currently. There is currently no reason to believe that this trend will reverse itself. A survey of the experimental opportunities and needs in FY1986 indicates that, as previously noted, a total of about 580 experimentalists will be active at SLAC. Of these, 75 will possibly come from foreign countries. We anticipate that this increase in user population will intensify

our already severe space and other support problems. One of the laboratory's goals is to provide some relief for these problems.

(2) Support of Stanford Synchrotron Radiation Laboratory (SSRL): SPEAR provides radiation sources for the Stanford Synchrotron Radiation Laboratory, a DOE-funded laboratory operated by Stanford University. At the beginning of FY1983 there were five beam lines operating, three originating in bending magnets and two in eight-pole wiggler magnets. During 1984 the addition of a sixth beam line originating in a 54-pole, variable gap permanent magnet wiggler was made. In the summer of 1983, two new straight sections were made available for source development by the removal of the rf cavities occupying those straight sections. The full energy capability of the storage ring is maintained by powering the remaining two rf cavities with higher power klystrons. Additional beam line developments are being planned in collaboration with outside groups.

In addition to the rather extensive facilities established at SPEAR, SSRL is well along with the construction of a seventh beam line, this one at PEP, to provide x-ray experimentation capabilities at approximately four times the energy available at SPEAR.

Under the letter agreement between the two laboratories, SLAC provides certain engineering and design services as well as substantial general and administrative support to SSRL on a cost reimbursement basis. The estimated volume of work to be done by SLAC for SSRL is approximately $ 13M in FY1985, and is projected to grow in future years.

Total work for others is shown in Table VI-1.

B. Subcontracting

Table VI-2 indicates the magnitude of funding flow from SLAC to other DOE contractors, universities and industry. The work done for SLAC by other DOE contractors is primarily in the nature of detector development and fabrication where the subcontractor has particular expertise or equipment not available at SLAC. Reprographics services represents the majority of subcontracting work

Table VI-1

WORK FOR OTHERS
(In Thousands of Dollars)

	FY1983	FY1984	FY1985	FY1986	FY1987	FY1988	FY1989	FY1990
SSRL								
Total	5,528.9	5,701.8	7,863.0	8,966.0	9,683.3	10,457.9	11,294.6	12,198.1
Without Dedicated Time	4,083.6	3,486.0	5,225.0	5,643.0	6,094.4	6,582.0	7,108.6	7.677.2
All Other Minus Japanese	1,381.9	1,075.2	1,140.0	1,231.2	1,329.7	1,436.1	1,551.0	1,675.0
Japanese	305.3	450.1	377.0	0.0	0.0	0.0	0.0	0.0
Total	7,216.1	7,227.1	9,380.0	10,197.2	11,012.0	11,894.0	12,845.5	13,873.2
Without Ded. Time	5,770.8	5,011.3	6,742.0	6,874.2	7,424.1	8,018.1	8,659.5	9,352.3
Dedicated Time	1,445.3	2,215.8	2,638.0	3,323.0[1)]	3,588.8	3,875.9	4,186.0	4,520.9

1) Escalation Factor FY1986-FY1990: 8%

Procurements, Subcontracts, and Transfers

(In Millions of Dollars)

	FY1984~	FY1985~	FY1986*	FY1987	FY1988	FY1989	FY1990
Transfers	0.6	0.1	1.1	1.1	1.1	1.1	1.1
University Subcontracts	0.4	0.6	0.7	0.7	0.7	0.7	0.7
All Other Subcontracts	55.4	146.8	99.9	86.4	99.0	75.1	76.8

~In then year dollars
*Escalation factor:1.0976
FY1987 - FY1990 in constant FY1986 dollars

Table VI-2

done for SLAC by Stanford University. The level of subcontracting by other DOE contractors and universities is expected to remain approximately level throughout the period of this report.

SLAC has been actively participating in the Federal Government/Industry Small Business Council of Northern California in furthering awards to small disadvantaged firms and small business firms. Participation has included small disadvantaged business seminars and fairs, monthly meetings of the Small Business Council of the San Francisco Bay Area, and use of the PASS system.

Each year SLAC submits for DOE approval its goals under Public Law 95-507. Generally, ambitious goals have been met. DOE awards for superior performance in the Small Disadvantaged Business program have been presented to SLAC in 1978, 1979, 1980, 1981, and 1982. Although SLAC has increased its goals each year, it is becoming increasingly difficult to meet these goals for a number of reasons; one being the increased expenditures for power, large equipment, and some specialized contracts which are available from large business only.

Small Business and Disadvantaged Vendor Subcontracting

	(Percent of Total Subcontracting)				
Small Business	FY1980	FY1981	FY1982	FY1983	FY1984
Goal	50.0	50.0	51.0	56.0	45.0
Actual	55.1	61.8	62.1	66.0	50.4
Small Disadvantaged Business					
Goal	4.2	4.5	5.0	5.5	5.5
Actual	4.3	5.2	8.8	8.0	4.8

Table VI-3

SLAC continues its efforts to increase small business and small disadvantaged business participation. Table VI-3 presents a summary of small business and disadvantaged business participation during the period FY1980 through FY1984.

BROOKHAVEN HIGHLIGHTS

APRIL 1983 – SEPTEMBER 1984

BROOKHAVEN NATIONAL LABORATORY
Upton, Long Island, New York 11973

A Word About BNL

Brookhaven National Laboratory is a multiprogram laboratory which carries out basic and applied research in the physical, biomedical and environmental sciences and in selected energy technologies. The Laboratory is managed by Associated Universities, Inc., under contract with the U.S. Department of Energy. The Laboratory employs over 3,000 people.

Established in 1946, BNL is located on Long Island, New York, on the site of what was known as Camp Upton, a training camp for U.S. soldiers during World War I and World War II. Now, in the center of the 5,265-acre site, over 250 buildings and other structures make up BNL's physical plant.

Brookhaven Today

With this issue we inaugurate a new format and a new policy for the Brookhaven Highlights. We are returning to an annual review, rather than continuing the biennial publication of the last 14 years. We are also making Highlights just that — highlights of the work accomplished by the Laboratory staff, with a brief summary of the overall mission of each department. Every year, we will highlight different aspects of the scientific and technical advances made at BNL. In addition, we shall include information about personnel and budgets, awards and honors, and the dozens of meetings the Laboratory hosted on an array of scientific topics.

One of the Laboratory's primary functions continues to be the building, operation and research use of large scientific machines. This involves high energy physics at the Alternating Gradient Synchrotron (AGS), nuclear physics at the Tandem Van de Graaff accelerator, and basic energy sciences at the National Synchrotron Light Source, the High Flux Beam Reactor (HFBR) and the Scanning Transmission Electron Microscope.

It is our intent to build and expand upon these strengths.

A step in this direction, a tunnel linking the Tandem Van de Graaff to the AGS, permitting the acceleration of ions as heavy as sulfur up to relativistic energies, has been approved and construction has begun. In our budget request for fiscal year 1986 is a booster synchrotron which, when inserted into the Tandem/AGS system, will not only appreciably increase the available proton intensity of the AGS, but will also extend the mass region of the relativistic heavy ion beams, up to gold. Long-range plans include a relativistic heavy ion collider where the Tandem/Booster/AGS will inject relativistic heavy ions into a colliding beam machine for the next generation of even higher energy interactions, and an upgrade of the HFBR to more effectively utilize the source of cold neutrons by adding substantial floor space for nine new advanced experimental instruments.

An interesting and valuable outgrowth of the variety of investigations made possible by our facilities is the rapid increase in the number of industrial scientists who have been added to our visitors list. This broadened community of users (complementing our academic and Laboratory personnel) and a more progressive governmental attitude toward patent policies are encouraging the use of Laboratory facilities and staff to assist in the country's technological development.

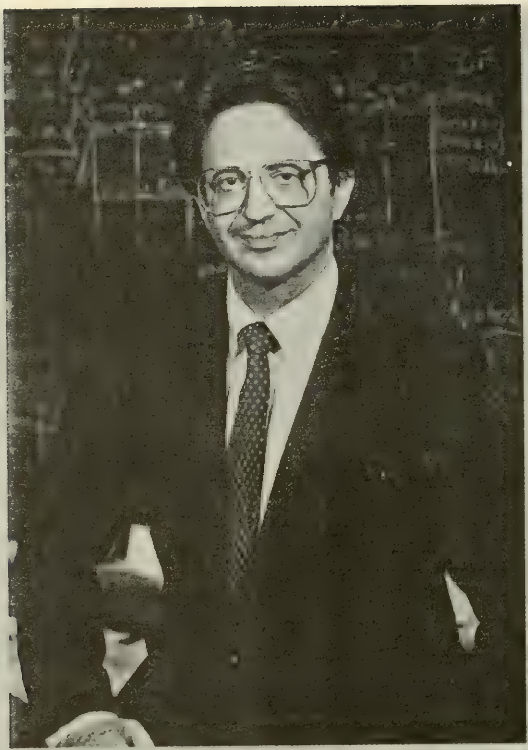
The Laboratory also opens its doors to students from high school through graduate school. The training programs are many and varied, and some are designed for science teachers to enable them to keep up with their research and with the latest scientific advances.

While the stories in this issue highlight only the major happenings of the last 18 months, ongoing research in many areas proceeds at a steady pace. As a multipurpose laboratory, BNL has directed its attention not only to physical sciences, but to energy technology, applied sciences, life sciences, and to various kinds of technical assistance for the U.S. Department of Energy and the Nuclear Regulatory Commission.

I hope the following pages will convey to you the breadth of our research, the enthusiasm of our staff and our part in the national scientific effort.

Nicholas P. Samios

Nicholas P. Samios
Director



The AGS: An Anniversary Salute

Since it began operating in 1960, Brookhaven's Alternating Gradient Synchrotron (AGS) has generated protons for both high energy and nuclear physics experiments. Now, about to celebrate its silver anniversary, the AGS also continues to generate superlatives.

The AGS: Then and Now

SPECIFICATION	1960	1984
Maximum energy	33 GeV	33 GeV
Usual operating energy	28.4 GeV	28.4 GeV
No. of targets	2	8
Injection system	protons	H^- ions
Type of preaccelerator	Cockcroft-Walton (CW)	RFQ (for polarized protons) & CW
	750,000 eV	750,000 eV
Linear accelerator injector	50 MeV	200 MeV
	110-ft long	537-ft long
No. of available modes	1	3
No. of magnets in AGS ring	240 main	240 main
	24 quadrupoles	36 quadrupoles
	36 sextupoles	36 sextupoles
		96 correction dipoles
Standard available intensity	2×10^{11} particles/pulse (p/p)	1.3×10^{13} p/p
Peak intensity achieved	3×10^{11} p/p	1.62×10^{13} p/p
No. of revolutions required to reach full energy	325,000	200,000
Amount of time required to reach full energy	1 second	0.5 seconds
No. of beam lines	12	16 external
		1 internal

The "World's Highest Energy Accelerator" — that's what the AGS became almost as soon as we began to circulate protons through the accelerator at energies as high as 33 billion electron volts (GeV). Though this happened almost 25 years ago, the idea that made the AGS possible surfaced about eight years earlier, in 1952. At that time, our pride centered on our newly operating Cosmotron, which could reach energies of 3 billion electron volts. Behind the scenes, however, we were already asking, "What would we do differently to build a bigger and better Cosmotron?"

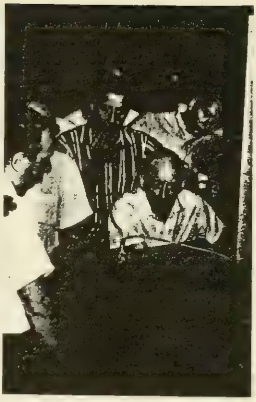
The revolutionary answer was "alternating gradient" or "strong" focusing. We found that the particles could be focused more strongly, and thus confined to much smaller dimensions, if the magnets through which they travel were arranged in such a way that the field gradients of successive magnets were alternated, first inward, then outward.

The smaller beam created by strong focusing permitted the use of magnets with much smaller cross sections. Because these were smaller and less expensive than larger magnets, they could be made stronger, bringing the accelerator to new energy plateaus. Since that time, alternating gradient focusing has been used worldwide as one of the guiding principles behind every new accelerator.

The AGS first reached its design energy on July 29, 1960, and the experimental program was off and running. It has been a most fruitful program, yielding an impressive number of significant discoveries, two of which, the J/psi particle and CP violation, have earned the AGS the distinction of having produced two discoveries which were awarded Nobel Prizes, in 1976 and 1980 respectively.

An AGS Chronicle

DATE	EVENT
Summer, 1952	Alternating gradient focusing developed at BNL.
1955	AGS construction began.
November 1956	AGS project moved from seven barracks to new Bldg. 911.
Apr. 13, 1959	Linac proton beam accelerated to 50 MeV on first attempt.
May 17, 1960	Beam first introduced into ring.
May 26, 1960	100 turns of circulation achieved.
July 29, 1960	First reached design energy of 30 GeV.
Nov. 1, 1960	Accelerator Department formed.
Sept. 13, 1961	AGS dedication ceremony.
1962	Muon-neutrino discovered at AGS by a Columbia/BNL collaboration; BNL/Yale team discovered anti-xi-minus particle.
Feb. 15, 1963	Round-the-clock operation began.
July 1964	Discovery of CP violation at AGS by James W. Cronin (U. of Chicago) and Val L. Fitch (Princeton) announced in Physical Review Letters. Nobel Prize awarded Oct. 1980.
August 1964	Multiturn injection first accomplished.
Dec. 3, 1964	Beam intensity reached 1.0×10^{12}.
1964	Omega minus particle discovered by BNL group using 80-inch bubble chamber at the AGS.
FY1967	AGS improvement program funded.
March 1968	First beam extracted in slowly extracted beam (SEB) mode.
November 1970	First operation of the new Linac at 200 MeV.
November 1973	New fast extracted beam (FEB) mode first used.
November 1974	The J particle discovered at the AGS by Samuel C.C. Ting (MIT), who shared Nobel Prize for this discovery in Oct. 1976.
1975	Charmed baryon discovered at AGS by BNL group using 7-foot bubble chamber.
1980	The 7-foot bubble chamber, the last bubble chamber at BNL, was retired.
March 1982	D-line began operating in east experimental area; MPS upgrade completed.
November 1982	H^- injection replaced proton injection.
Jan. 17, 1983	First operation of new, third mode, single bunch extraction (SBE).
June 1983	New polarized H^- ion source achieved record intensities in excess of 12 μA.
December 1983	AGS reached record intensity of 1.62×10^{13} p/p.
Feb. 14, 1984	RFQ Linac worked on its first try; first RFQ to inject into a linear accelerator.
February 1984	HEDG Task Force recommended AGS II.
July 13, 1984	Polarized proton experimentation began, operating at 16.5 GeV, highest energy ever for polarized protons.
Fall 1984	Construction began on tunnel to link Tandem and AGS for heavy ion beam acceleration in the AGS.



Main AGS Control Room on Friday, July 29, 1960, at approximately 4:00 p.m.

The AGS: An Anniversary Salute (continued)

Superlatives continued to mount for the AGS in 1984. By the end of the year, the AGS had accelerated over 10^{21} (1,000,000,000,000,000,000,000) protons in its lifetime, more than any other high energy machine, earning the title of "World's Most Prolific Accelerator."

In 1984, the AGS also became the "World's Most Polarized Accelerator." The AGS claimed this distinction in July, when we began delivering beams of polarized protons to experimenters.

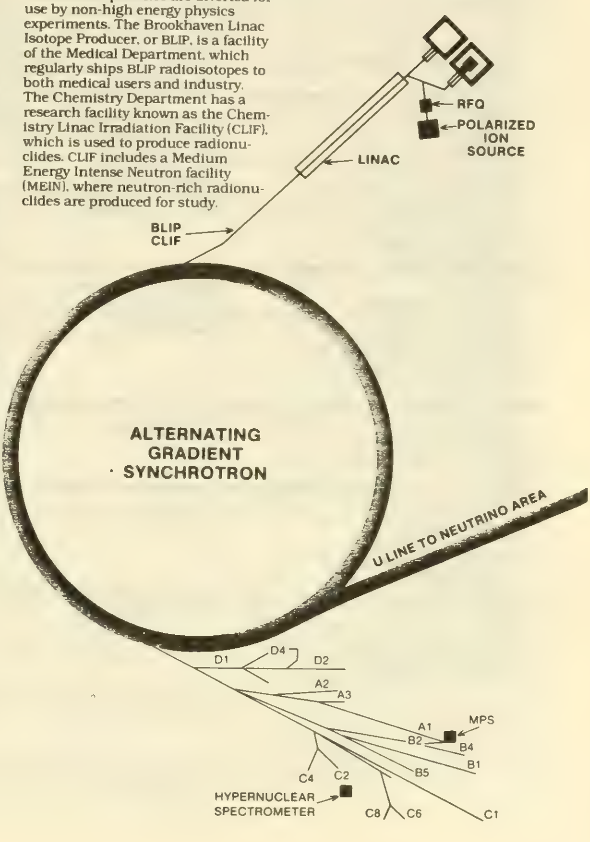
In order to accelerate polarized protons, which spin in the same direction, we had to modify the AGS rather extensively. This work began in 1982, and included:

- creating and commissioning a new ion source for polarized negative hydrogen (H^-) ions.
- developing a new pre-accelerator, a radio frequency quadrupole (RFQ), to replace the Cockcroft-Walton.
- building, then installing in the AGS ring, 12 fast (1.6 microseconds) pulsed quadrupoles and power supplies for 96 correction dipoles.

Milestones came quickly. On June 17, 1983, we set a new world record for output of polarized ions with the new source; on February 14, 1984, the RFQ worked beautifully on its first try, accelerating 40% of the injected beam; on February 23, a beam of polarized protons was accelerated to 200 MeV in the AGS injector, the Linac; on March 8, polarized protons were accelerated into the AGS ring for the first time; and on July 13, researchers began experimenting with these spin-aligned particles.

BLIP, CLIF and MEIN

Near the end of their journey down the 537-foot-long, 200 MeV Linac, some excess particles are diverted for use by non-high energy physics experiments. The Brookhaven Linac Isotope Producer, or BLIP, is a facility of the Medical Department, which regularly ships BLIP radioisotopes to both medical users and industry. The Chemistry Department has a research facility known as the Chemistry Linac Irradiation Facility (CLIF), which is used to produce radionuclides. CLIF includes a Medium Energy Intense Neutron facility (MEIN), where neutron-rich radionuclides are produced for study.



AGS Physics Program

Today, exciting research abounds at the AGS. To accommodate many different types of experiments, the AGS can deliver protons in three modes and send protons to as many as 11 experiments simultaneously. These experiments were part of the approved AGS physics program in 1984 though not all were ready to receive beam.

Type of Experiment	No.	Beam Line	Collaboration
Rare K Decays These experiments, which probe mass scales in the tens of TeV (trillion electron volt) range, could lead to a new breakthrough in the understanding of such fundamental questions as the origins of flavors and mass.	777	D3	BNL/Yale/SIN/Washington ($K^+ \rightarrow \pi^+ \mu^+ e^-$)
	780	A3	BNL/Yale ($K^0_L \rightarrow \mu e$)
	787	C4	BNL/Carnegie-Mellon/Columbia/Princeton/TRIUMF ($K^+ \rightarrow \pi^+ \nu \bar{\nu}$)
	791	B5	Stanford/UCLA/Penn/Temple ($K^0_L \rightarrow \mu e$)
Polarized Protons Exp. 748 focused an unpolarized beam on a polarized target and found spin effects to be three times greater than predicted. Exp. 782 collected data on spin-spin effects, and Exp. 785 measured the asymmetry in the distribution of specific produced particles when polarized protons strike non-polarized hydrogen.	748	D1	Michigan/BNL/Maryland/Miami/Notre Dame/Texas A&M/ETH Zurich/Copenhagen
	782	D1	Mich/BNL/Maryland/Miami/Notre Dame/Rice/Texas A&M/ETH Zurich
	785	C1	BNL/Minn/SE Mass
Neutrinos To test the Weinberg-Salam theory of electroweak interactions, Exp. 734 measures elastic neutrino-electron scattering. Exp. 776 searches for signs that neutrinos oscillate, to determine whether they have mass.	734	U	BNL/Brown/KEK/Osaka/Penn/Stony Brook
	776	U	Columbia/Illinois/Johns Hopkins
Antineutrons A unique tagged antineutron source was used to study the interactions of antineutrons in hydrogen.	767	C8	BNL/Houston/Penn State/Rice
New Particle Search In 1983, a long-lived state with mass about 2220 MeV was detected at SLAC. Exp. 789 looked for this particle in antiproton-proton interactions.	789	C1	NYU/BNL
QED A test of QED, this experiment precisely measured the energy difference between levels in muonic helium.	745	D4	Columbia/CERN/BNL

RFQ Preaccelerator

Until this year, we accelerated H ions to initial energies of 750,000 electron volts only in the Cockcroft-Walton. But we knew this huge preaccelerator would be very clumsy for polarized protons. So, we turned to a new concept: the much smaller radio frequency quadrupole, or RFQ.

On March 19, 1984, we ran the two-meter-long RFQ for the first time, accelerating 4×10^9 protons in the AGS, while preserving 60% polarization to above 4 GeV and 25% to above 6 GeV. The RFQ became the first such device to be used in an operating accelerator. Our RFQ is also unique in that it is the only one that accelerates polarized negative hydrogen ions, which, after electrons are later stripped away, end up in the AGS as polarized protons.

Machine Upgrades

In addition to an upgrade of the On-Line Data Facility, our construction efforts at the AGS in 1984 resulted in:

- an internal target for Exp. 778, to study nuclear fragments in FY85.
- a betatron tune meter, a monitor which measures, once per acceleration cycle, the horizontal and vertical tune of the AGS.
- an injection position monitor, which measures the position and angle of the beam at injection, and a similar device that also measures the positions of individual bunches of particles, the individual bunch coordinate monitor.
- a series of five new extraction magnets.
- a new U target station to provide for a 50% increase in neutrino beam flux.

The AGS: An Anniversary Salute (continued)

Type of Experiment	No.	Beam Line	Collaboration
Glueballs The Multiparticle Spectrometer (MPS) is used in searches for glueballs — pure, yet-to-be-observed particles made of pure gluons, the stuff that holds quarks together.	747	A1	BNL/CCNY
	769	A1	Notre Dame/Brandeis/BNL/CCNY/Duke
	771	B2	BNL/Florida/SE Mass/Indiana
Hyperon Decays The MPS was also used by Exp. 751 to study the radiative decay modes of hyperons.	751	B2	Brandeis/SE Mass/Notre Dame/Duke
CP Violation This experiment can determine whether the superweak CP violation models are correct — that there is no difference in the neutral to charged two-pion decay ratios of the K^0_L and K^0_S mesons.	749	A3	BNL/Yale
Omega Minus This study of Ω^- production and decay uses a processor that can handle 100,000 omega minus events per second.	766	B5	Columbia/Mass/Mexico/Fermilab
Two-Body Exclusive Reactions This test of QCD predictions observed how particles recombine when the angles of their collisions change.	755	C1	BNL/Minn/SE Mass
Nuclear Transparency The energy loss of energetic protons in a variety of nuclei was measured by Exp. 790.	790	C1	BNL/MIT/Minn/SE Mass
Dibaryons, Hypernuclei With the hypernuclear spectrometer, Exp. 773 searched for particles called strange dibaryons. Exp. 781 studied the effect of spin on lambda hypernuclear levels.	773	C2	Brandeis/BNL/Houston/CMU/MIT/New Mexico/Vassar
	781	C2	BNL/MIT/CMU/Houston/NYU/Vassar
Magnetic Moments This experiment measured the magnetic moment of the negative sigma hyperon.	723	C4	W&M/Boston/CMU/CIT/Wyoming
Muon Spin A materials science experiment, this study probes lattice structures with muons.	754	D2	Bell Labs/BNL/W&M/George Mason/Virginia State

Any machine which can accelerate both polarized and unpolarized protons, deliver protons to experimenters in three different beam modes, and serve up to 11 different experimental beams at one time is certainly a candidate for another superlative: "World's Most Versatile Accelerator." And future plans for the AGS make its claim to this title even stronger.

We have already begun working on a project which will introduce a whole new type of physics research at the AGS — the transfer of heavy ions from the Tandem Van de Graaff and the acceleration of heavy ion beams for experiments with fixed targets, planned to begin in 1986. Last fall, with funding from the Nuclear Physics Division of the U.S. Department of Energy (DOE), we began to construct the 2000-foot-long heavy ion transfer line.

The future of the AGS was the subject of an intensive study by the AGS II Task Force, formed by the High Energy Discussion Group. The Task Force held a series of four meetings in the winter of 1983-84 and reported on its recommendations in February 1984. Based in part on those recommendations, a five-year plan was submitted by BNL to DOE in March, emphasizing the following objectives:

In the next three years, to

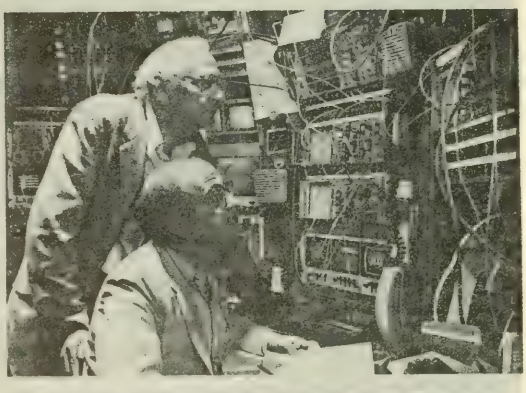
- improve AGS operating reliability from 70% to 90%.
- increase the overall duty factor from 20% to 40% (90% microstructure and 45% macrostructure).
- increase intensity to 3-5 × 10^{13} protons per pulse by adding a 1 GeV booster ring.
- provide increased flexibility in multiple beam operation.

Completing these near-term objectives would require, among other efforts, a major revamping of the AGS control system and the construction of a second RFQ to replace the Cockcroft-Walton.

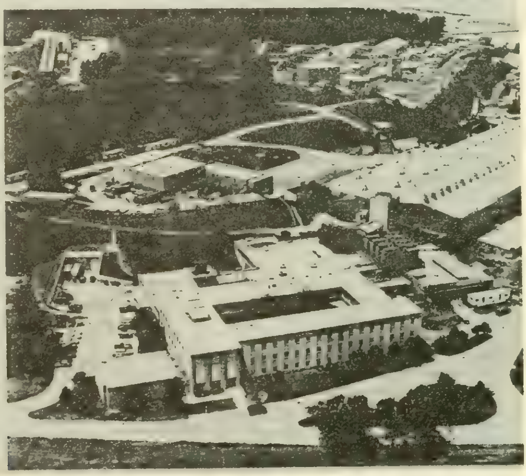
In the longer term, to

- increase the duty factor for the slowly extracted beam by adding a stretcher ring.
- increase intensity to 10^{14} protons per pulse by further improvements to the AGS and the booster.

The booster ring, which figures importantly in both our long-term and short term plans, would be built between the existing 200 MeV Linac and the structure which housed the original AGS 50 MeV Linac injector, to serve both the proton and heavy ion programs at the AGS. This booster is also critical to our plans for a Relativistic Heavy Ion Collider (RHIC). A proposal for RHIC has been submitted to DOE. If it is approved, the AGS will go on to still another duty, serving as the injector for this large accelerator, which would collide ions up to $A = \sim 200$ at ~ 100 GeV/nucleon at a luminosity of 10^{27} cm^{-2} s^{-1}.



Right, above: Larry Ratner of BNL (standing) and Alan Krisch, University of Michigan, monitor the data on the control room computer screen as polarized proton experimentation begins at the AGS.



An aerial view of the Alternating Gradient Synchrotron. The Linac (upper left) is the injector for the AGS ring. The large building in front of the ring houses the Accelerator Department and the AGS control room. Other structures in the area are used to service the accelerator and for experiments.

The Big Machines

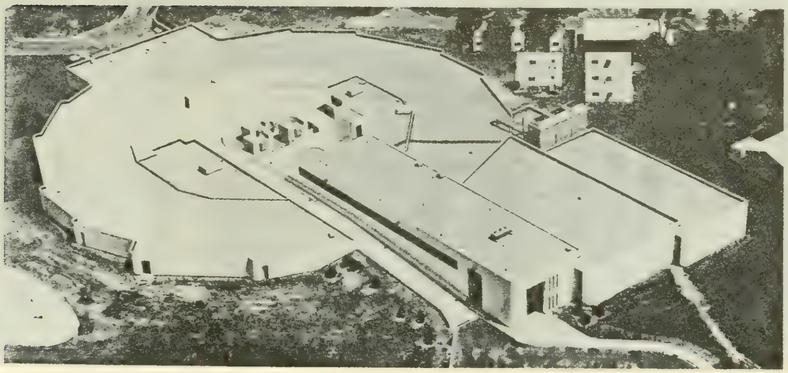
Brookhaven has always maintained a strong spirit of cooperative research. Large numbers of visiting scientists, primarily from universities, use the Laboratory's unique facilities to do research not possible otherwise. BNL also encourages interaction with industry in the application of new knowledge.

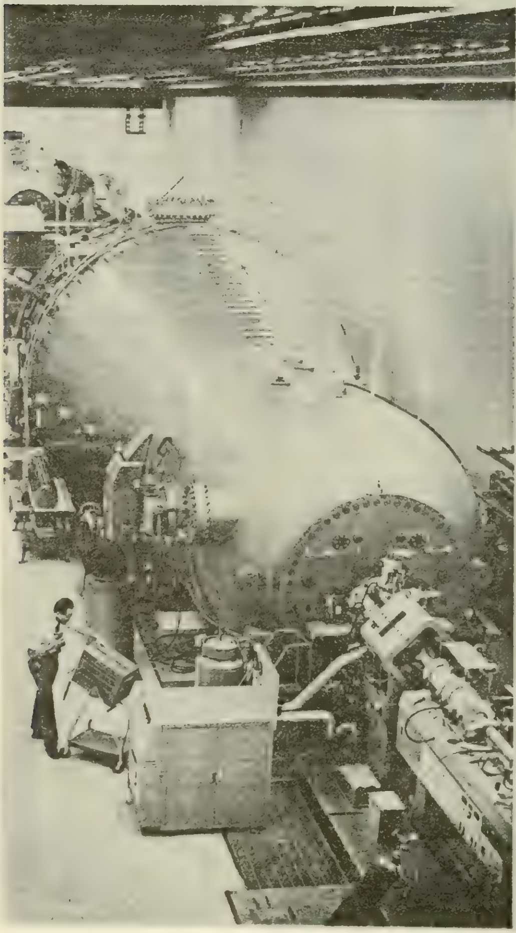
Close to 30 facilities are available for non-proprietary, usually basic, research. Proprietary research may be performed under a formal agreement between BNL and the outside user.

Previous pages described Brookhaven's Alternating Gradient Synchrotron, a venerable machine that has served literally thousands of users in its 25-year history. Highlighted on these pages are BNL's other major facilities that serve the scientific community of the world.

National Synchrotron Light Source (NSLS)

The NSLS is the world's brightest source of ultraviolet radiation, and x rays will be available to users in 1985. A wide range of research equipment is available for basic and applied studies in condensed matter, surface studies, photochemistry and photophysics, lithography, crystallography, small angle scattering and x ray microscopy. Proprietary work can be done on a full cost recovery basis, with the option of retaining title to inventions. In 1984, 137 scientists did experiments at the NSLS.





High Flux Beam Reactor (HFBR)

The 60-megawatt HFBR provides an intense source of particularly pure thermal neutrons. Emphasis is on the study of fundamental problems in solid state and nuclear physics and in structural biology and chemistry. Various instruments are available, and special equipment exists for experiments at high and low tempertures, high magnetic fields and high pressure.

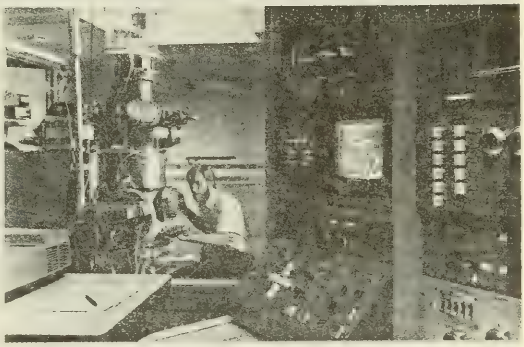
Tandem Van de Graaff Accelerator Facility

A wide selection of light and heavy ion beams are available at this machine for applications in materials research. Efforts are made to facilitate users' work by having the machines operate around-the-clock, by developing easy-to-use equipment and by providing technical assistance in setting up experiments.

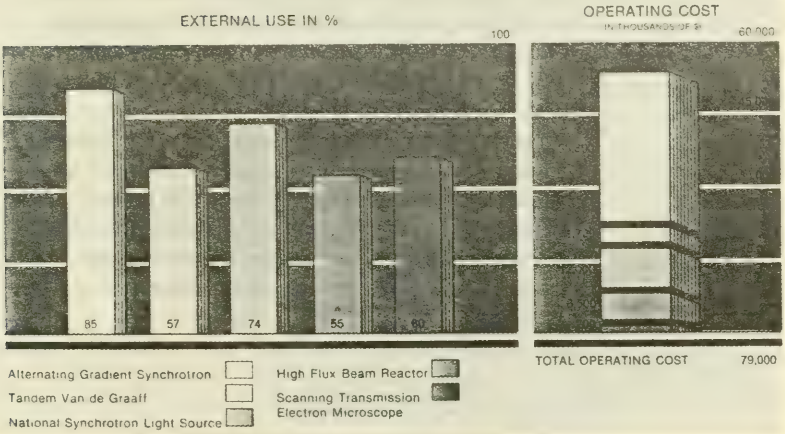
The Big Machines (continued)

Scanning Transmission Electron Microscope (STEM)

STEM provides a 2.5 angstrom resolution on biological specimens. The microscope can also determine molecular weight and mass distribution within single macromolecules and complexes. Research time on the machine is allocated in one-week blocks by the STEM Advisory Committee.



MAJOR RESEARCH FACILITIES
SUPPORTING UNIVERSITIES OR INDUSTRY



Accelerator Department

Since 1947, when we first conceived the Cosmotron, Brookhaven has been a leader in advanced accelerator technology. Under the auspices of the Accelerator Department, we have incorporated that technology into the development and operation of high energy facilities, as well as non-accelerator applications.

At present, our principal facility is the Alternating Gradient Synchrotron (AGS). We are also preparing concepts for future accelerator applications. Some of our skills are being applied to the national effort behind the proposed Superconducting Super Collider. During 1984, we also submitted two proposals to the U.S. Department of Energy, one for a booster ring to push AGS particles to higher energies and one for a Relativistic Heavy Ion Collider.

Probably our best-known spin-off is the Power Transmission Project, a prototype system for the inexpensive transmission of electrical power. The techniques for cooling the superconducting cables which act as the system's power transmission lines were borrowed from accelerator technology.

...There Stands a Source

From the Linac to the AGS ring, down the experimental beam lines to the targets, all our efforts at the Alternating Gradient Synchrotron (AGS) are geared towards one goal: successful high energy and nuclear research. But behind all this — behind every successful accelerator, in fact — there stands a source.

That source is the wellspring for all the particles that circulate through the accelerator. In the AGS, these particles have always been protons, but over the years those protons have been derived from several different sources. At present, we at BNL are working on two source projects, with our primary goal to increase experimental opportunities at the AGS.

The first of these sources — an intense polarized negative ion source — is a key component in the new high energy polarized proton program at the AGS. The negative hydrogen (H^-) ions produced in this source are polarized, which means they all spin in the same direction.

The creation of polarized H^- beams begins with the separation of hydrogen molecules, each into two hydrogen atoms. From these, we magnetically weed out all particles having one spin direction, leaving neutral hydrogen (H^0) atoms, all with the same polarization. These H^0 atoms then collide with an energetic, neutral cesium beam (Cs^0). The collision promotes a charge exchange which yields a beam of H^- ions. After entering the AGS ring, the polarized H^- ions pass through a very thin carbon foil. There, two electrons are stripped from them, leaving only polarized protons.

Work on the polarized negative ion source began in early 1981. In July of 1983, we measured beam currents in excess of 15 microamperes (μA), a new world record for this type of source. By September 1984, that had climbed to 25 μA.

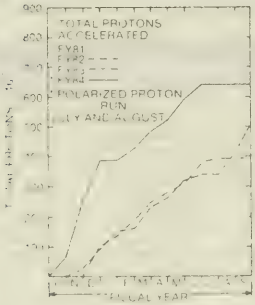
The present current from the polarized negative ion source is sufficient for the polarized proton research that began at the AGS in July 1984. These beam currents, however, are considerably lower than beams extracted from our regular negative ion source, which is still used for the other experimental programs at the AGS. Now we are trying to prove that it is possible to construct a single source from which we can extract milliamperes of either unpolarized or polarized negative ions. Not only would this permit us to serve all our present types of experiments with only one source, but the availability of such a source would also open up a completely new experimental physics domain. Our challenge here, then, is primarily to create an ion source that can achieve intensities sufficient for polarized and unpolarized experimentation.

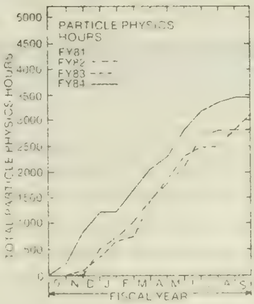
Satisfying those demands requires that we create a next-generation source capable of beam currents as high as 25 milliamperes, in both the polarized and unpolarized beam modes. We believe a combination of two new features should help us realize that goal.

Like the present polarized negative ion source, the new source will start with neutral hydrogen atoms. But we will bring these H^0 atoms to very low temperatures — down to around seven kelvins. The cooling will slow the atomic beam considerably, increasing its density (and the final beam intensity) by at least an order of magnitude.

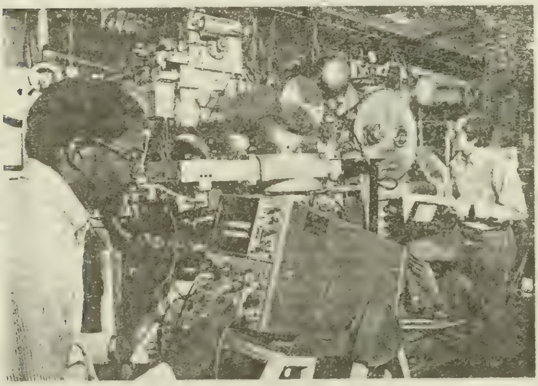
The second increase in intensity will come from using negative deuterium (D^-) ions, rather than neutral cesium atoms, in the charge exchange process. To do this we will build a ring magnetron, which will surround the oncoming H^0 beam with D^- ions that will cross-collide with the atomic beam. Theoretically, this could increase the polarized H^- intensity by two orders of magnitude.

Feasibility tests will be conducted on this idea, now in the conceptual stage, in 1985. Based on the successful outcome of those studies, we would design and construct the next-generation polarized ion source in 1986.





One measurement of just how busy the sources at the AGS have been is the total number of protons accelerated in any given year. The chart at left, which covers each fiscal year since 1981, accumulates that total month by month. How that correlates with the hours available for experimentation can be seen by comparing these charts. The number of hours the AGS runs varies from year to year, depending on the the current levels of funding and maintenance requirements.



James Alessi gives the polarized negative ion source a once-over, while Abovi Kponou (foreground) monitors its performance with an oscilloscope.

The Focus Is on Neutrinos

Exploring the particle world requires huge amounts of experimental planning and support activities. A case in point is neutrino experimentation, which benefited from many of our efforts in 1984 at the Alternating Gradient Synchrotron (AGS). In particular, we developed an experimental area for a new neutrino experiment, 776, and designed and constructed a particle focusing system to serve both 776 and existing experiment 734.

Though both experiments rely on the newest in detectors and accelerator technology, the neutrinos they focus on have been around as long as our universe, having evolved with the weak interaction, the force associated with radioactivity and nuclear decay.

Brookhaven's association with these elusive particles is not new either. In 1962, AGS physicists performed the world's first high energy experiment, which resulted in the discovery of the muon-neutrino. Then, in 1974, an unusual neutrino event occurred when neutrino experimentation at Brookhaven moved to the 7-foot bubble chamber. This later proved to be the first single charmed particle, a charmed baryon. Today, researchers here look for neutrinos with huge detectors. The detector for Exp. 734, for example, weighs about 200 tons, and Exp. 776's weighs over 300 tons.

Since 1981, Exp. 734 has been measuring neutrino-electron elastic scattering, to test the Weinberg-Salam theory of electroweak interactions. Beginning in November 1984, Exp. 776 will search for signs that neutrinos can change from one type of neutrino to another (oscillate), to determine whether they have any mass. If the mass is small, that change would occur at AGS energies, slowly and over a long distance, so the detector for Exp. 776 is located almost one kilometer (0.6 miles) north of the AGS ring. In addition to providing a building there, we support the experiment with utilities, carpentry, cooling and surveying. Another of our contributions was to build, test and measure the five toroid magnets used in the detector system, each of which weighs about 38.5 tons and is 18 feet in diameter by seven inches thick.

When the first beam of neutrinos strikes the toroids in November 1984, particles will also pass through two new narrow-band neutrino horns for the first time. Called neutrino horns (because each of the two major components resembles a long, slim horn), the 33-foot-long focusing system will rarely see a neutrino. What will pass through it will be the pi (π) mesons produced when the AGS fast extracted proton beam strikes a tungsten-rhenium target. The horns will focus the π mesons into a parallel beam with a well-defined energy, which will travel out of the horns and down the U-line tunnel toward the experiment. Along the way, a large fraction of the π's will decay, and one product of the decay will be neutrinos.

The new horns represent a several-fold improvement over previous horns. First, because the location has been moved to allow a longer decay space, and because the larger horns can focus more π mesons, we will get more decay products and thus more neutrinos, for an increase of about a factor of ten in neutrino intensity, for narrow band running.

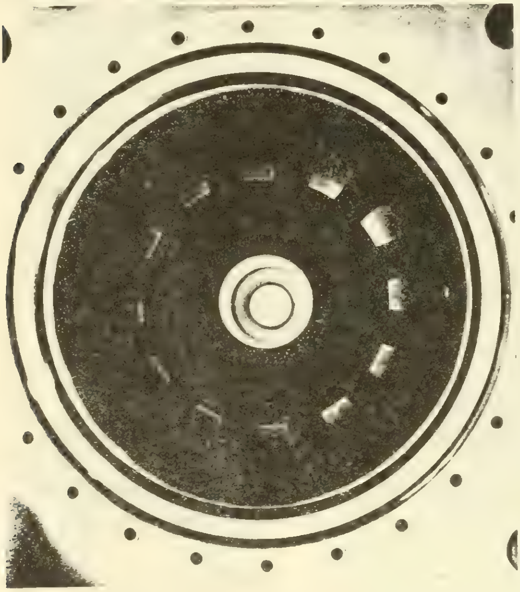
Much of our effort went into horn design. Earlier horns, placed in earthen tunnels to shield against radioactivity, were difficult to repair or change. The components of the new horns are positioned on flatbeds for mobility and shielded by movable

concrete slabs 25 feet thick, so the new horns will be both safer and easier to maintain.

Several other AGS activities have also enhanced the neutrino experiments, particularly our continuing effort to increase AGS intensity. While important to all experiments at the AGS, the record intensity of 1.62×10^{13} protons per pulse that we achieved in December 1983 is particularly helpful to the neutrino experiments: the more protons available, the more π mesons will be created to decay into neutrinos.

Similarly, our increased understanding and refinement of the AGS radio frequency system is helpful because it allows us to accelerate more of the protons injected into the AGS. And with 10% more operating time in 1984, experiments like 734 and 776 had more time and more neutrinos, so that researchers were able to collect more data.

If pi mesons could see, this would be their view as they enter the new neutrino horns at the AGS. The two parts of the focusing system are called neutrino horns because, after passing through them, the pi mesons decay into the neutrinos that are analyzed by the detectors of Experiments 734 and 776.



A Quest for Quark Matter

Understanding our universe has been somewhat like peeling the layers of an onion. First, physicists looked into the atom and found a nucleus surrounded by orbiting electrons. Then they peered into the nucleus and learned it was composed of particles called neutrons and protons, known collectively as hadrons. Now they contemplate those hadrons, which are believed to consist of fundamental entities called quarks, held together in combinations of three by other fundamental entities called gluons.

The quark-gluon symbiosis is so tight that free quarks and/or gluons have never been observed. But theory indicates that if heavy atomic nuclei collide head-on at energies approaching the speed of light (relativistic), some nuclei will become heated to temperatures and densities so extreme that their constituents will temporarily lose their identities as neutrons and protons, and become a hot gas of quarks and gluons. That would create a new form of matter: a quark-gluon plasma. Known to physicists as quark matter, we believe its properties would reflect the conditions that existed at the earliest moments following the birth of the universe.

There is great interest in creating quark matter, both on the part of nuclear physicists, who have always studied nucleus-nucleus collisions, and high energy physicists, who have long used high energies to probe the most basic constituents of matter. During 1984, Brookhaven was a center of activity for both physics communities in formulating the proposal for RHIC, a relativistic heavy ion collider designed to recreate the conditions necessary to form quark matter.

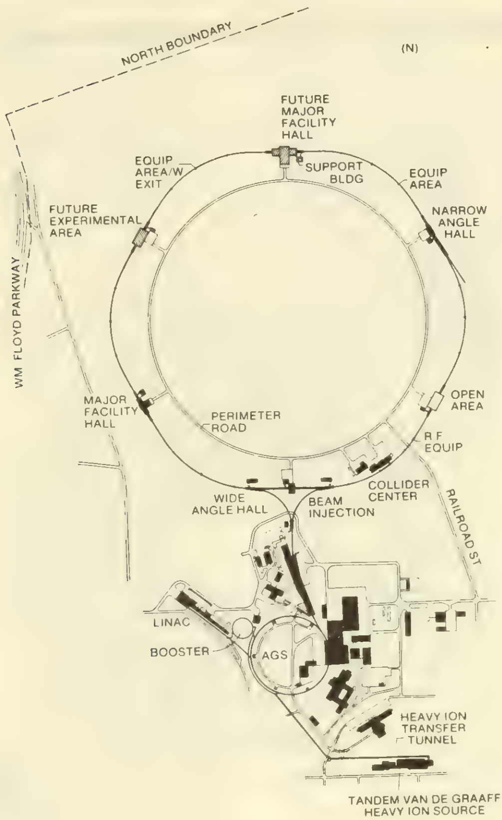
Our RHIC proposal, which was formally submitted to the U.S. Department of Energy (DOE) at the end of 1984, calls for construction to begin in 1987 on a collider to be completed in 1991. Brookhaven is an ideal location for a relativistic heavy ion collider, because most of the injector system and the conventional facilities already exist.

Central to a RHIC injector is the existing Alternating Gradient Synchrotron (AGS), as well as two other components which are independently important to new physics research at the AGS and should be completed well before RHIC construction would begin. The first component, for which ground was broken in the fall of 1984, is a transfer line that will send heavy ions from Brookhaven's Tandem Van de Graaff accelerator to the AGS. A proposal for the second component, a booster ring to push the heavy ions to higher energies before they enter the AGS, was submitted to DOE in mid-1984.

The 2.4-mile circular tunnel that would house RHIC already exists on the north side of the Laboratory property. Also, there are the tunnels from the AGS, support buildings, three experimental areas, a central control building and a complete helium refrigeration system, the world's largest. All were built for the Colliding Beam Accelerator (CBA) project, before the project was terminated in July 1983. Our CBA work also left us with an experienced superconducting magnet group and very large facilities for constructing, assembling and testing superconducting magnets.

The collider that would make use of these attractive assets would accelerate all the ion species, up to and including uranium, while the design is optimized for beams of gold. Heavy ions would circulate in two opposing rings, colliding at six points with an energy near 100 GeV per nucleon in each beam — more than enough energy, it is predicted, to form quark matter. This is equivalent to about 250 GeV for protons, which RHIC could also accelerate.

To reach this energy, while holding costs down, RHIC's superconducting magnets would operate at the relatively low magnetic field of 3.5 tesla. The bunches of heavy ions injected would fill the RHIC ring in box-car fashion, one after the other, an approach that is both simple and cost effective.



Another consideration in our RHIC design was the effect of intrabeam scattering, which occurs within a beam when two particles traveling together interact with each other. When observed elsewhere in protons, this scattering had had little impact. But our calculations now show that intrabeam scattering will cause a bunch of heavy ions to grow, increasing the beam's dimensions and promoting a loss of beam particles, which is undesirable. Larger apertures to contain the beam, more quadrupole magnets for stronger focusing and more powerful radio frequency apparatus to provide voltage will help RHIC accommodate this effect

That has been the crux of our challenge: to take advantage of existing assets while meeting the new demands presented by heavy ions RHIC may be designed to fit into an existing tunnel, but in its design and its implementation, it is a new and truly unique machine which should allow us to enter a completely uncharted region to study the fundamental properties of a new state of matter — quark matter.

The RHIC proposal would have heavy ions traveling through several of Brookhaven's facilities. From the source at the Tandem Van de Graaff accelerator, heavy ions would travel through a 2000-foot transfer tunnel to the proposed booster ring, which would be built between the Linac and the AGS, to be raised to higher energies. Then they would enter the AGS, be accelerated to AGS energies, and exit to the beam injection tunnel to enter RHIC's two rings. There, traveling at energies of 100 GeV per nucleon, the heavy ions would collide at six points around the ring for study by researchers at four experimental areas.

Physics Department

Theory and experimentation go hand in hand in each of the areas of fundamental research explored by the Physics Department: elementary particle (or high energy) physics, solid state (or condensed matter) physics, and nuclear physics. Our solid state research is concerned with the cohesive forces that bind atoms together to form the various phases of condensed matter. The basic nature of the structure of nuclei and nucleons, as well as their interactions, command our nuclear physicists' attentions. And in high energy physics, our elementary particle physicists probe the fundamental properties of the world of the incredibly small. Now engaging the interest of a growing number of our nuclear and particle physicists are the study of very high density matter and the methods for production of quark matter with the Relativistic Heavy Ion Collider proposed by the Laboratory.

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The Implications of CP Violation

In their search for a fundamental theory of nature, physicists often use simplicity and symmetry as a guide. But Nobel Prize-winning work done at Brookhaven in the early 1960's showed that one basic symmetry principle breaks down in a tiny corner of the subatomic world. Today at Brookhaven, our high energy theorists and experimentalists continue to try to understand this interesting phenomenon, known as CP violation.

It was long thought that the physics would be identical if, in any process, all particles were replaced by their antiparticles (charge conjugation, or C) while all of their motions were replaced by their mirror images (parity, or P). Under this symmetry, for example, the rate at which a lambda particle decays into a proton and a negative pion would equal the rate at which a lambda antiparticle decays into an antiproton and a positive pion, i.e. $\Lambda \rightarrow p+\pi^- = \bar{\Lambda} \rightarrow \bar{p}+\pi^+$. And, indeed, this symmetry is true for the strong and electromagnetic forces that hold nuclei and atoms together. It is also true, to an extremely high degree of accuracy, for the weak forces associated with radioactive decay.

It was only in 1964 that this symmetry principle was thrown into doubt, when James W. Cronin, Val L. Fitch and their collaborators did an accurate measurement of the decays of neutral K mesons (K^0) at BNL's Alternating Gradient Synchrotron (AGS). Only after all other attempts to explain their results failed was the strongly held belief in this symmetry principle overcome. For discovering CP violation, Cronin and Fitch received the Nobel Prize in physics in 1980.

Today, 20 years after that discovery, there has been no experimental evidence of CP violation in any system other than the weak K^0 decays. Brookhaven theorists recently calculated the predictions of the currently favored theory of weak decays — the Kobayashi-Moskawa model — and found that the predicted size of other CP violations are always very small. For example, the predicted difference between $\Lambda \rightarrow p+\pi^-$ and $\bar{\Lambda} \rightarrow \bar{p}+\pi^+$ is less than one part in a million. For some new particles, especially those containing the bottom quark, much larger differences have been found, but the basic process itself is rare, so the prediction has not yet been tested by experiment.

The K^0's, however, are an exception, in terms of the amount of CP violation in the system, and so have been the focus of many BNL experiments. The K^0 and its antiparticle, the $\bar{K}^0$, share nearly all the same properties. Most important, they have exactly the same mass, as well as the same charge. As a result of a fundamental principle of quantum mechanics, they can "mix" and form two new particles, which are partly K^0 and partly $\bar{K}^0$. It turns out that these new particles have nearly the same mass, but very different lifetimes before they decay, two features that make them excellent probes of CP violation.

This was the basis of a very sensitive experiment aimed at uncovering the source of CP violation, which was completed at the AGS in 1984. Experiment 749, a BNL/Yale collaboration, asked the basic question: Does the CP violation result from the mixing of the K^0 and the $\bar{K}^0$, or is there some fundamental violation of CP in the interaction of the quarks which make up the K meson?

The so-called "superweak" theories say the CP violation comes entirely from the mixing, while other theor-

ies, like the Kobayashi-Moskawa model, predict additional CP violation effects. If the phenomenon results entirely from the mixing, then the ratio of the rate of the long-lived K decay into any particular particles, to the ratio of the rate of the short-lived K decay into the same particles, *must* be the *same* for all possible final particles.

Experiment 749 was designed to compare, precisely, this ratio for the two possible final states, $\pi^+\pi^-$ and $\pi^0\pi^0$, using the intense K beams at the AGS. About ten times the world's previous sample of the rarest of these decays, the $K_L \to \pi^0\pi^0$, was accumulated. This was important because accurate measurement of this ratio requires that many decays be measured. Based on these data, we concluded that the ratios could, at most, differ by a small amount.

This result is important to theories of particle decays. Our theorists have been involved in an extensive program to determine the precise form of the interactions that give rise to these decays. These studies are closely related to three topical issues: the lifetime of the recently discovered B meson, the nature of CP violation as measured in Exp. 749, and the mass of the anticipated top quark. As things now stand, with the long lifetime of the B and the near equality of the ratios of the K decay rates as determined by Exp. 749, the Kobayashi-Moskawa model predicts a lower bound for the top quark mass.

Both theoretical and experimental work is continuing in this exciting area, where physicists are on the verge of making a definitive conclusion about the nature of the weak decay interaction. Contributing to that will be BNL's unique capability of studying unusual and rare decays of the K mesons. These decays provide a sensitive means for learning about the fundamental forces of nature, and we have committed many resources over the next few years to carrying out several rare K decay experiments at the AGS.

Ling Lie Chau (left) and William Morse discuss the data collected by AGS Experiment 749 and its ramifications for theories of CP violation.

Hyperons: The Inside Story

Looking inside an atomic nucleus is as predictable as gazing at a clear nighttime sky. Just as we expect to see certain stars and planets in the heavens, we count on "seeing" protons and neutrons (nucleons) in the nucleus. Still, unexpected things like shooting stars and satellites sometimes mingle with the constellations. In the subatomic world, some strange things, like lambda and sigma particles, can enter a nucleus.

Collectively, these strange particles are called hyperons, and when they wander into a nucleus, they join with the nucleons there to form a hypernucleus. Hyperons, like the nucleons, are composed of three fundamental entities called quarks. With hyperons, however, one of those quarks is a strange quark, which accounts for the particle's "strangeness."

In a continuing program at the Alternating Gradient Synchrotron (AGS), our nuclear physicists are forming hypernuclei, to study their properties, to learn about hyperons and the quarks of which they are made, and, in particular, to understand the interactions of the lambda particle.

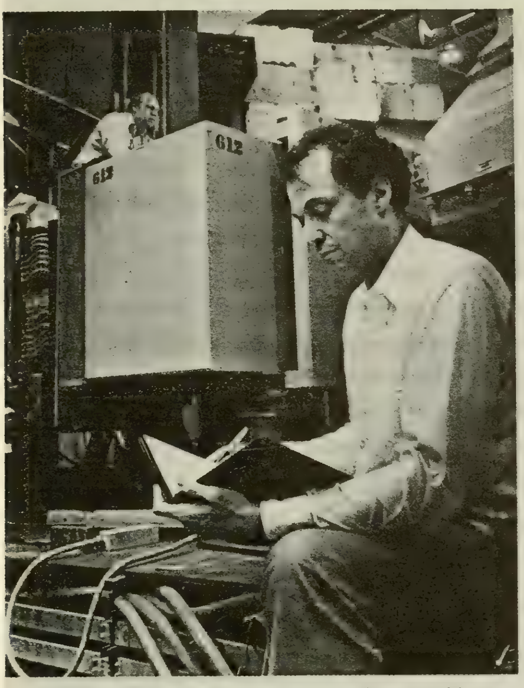
Until a few years ago, the hypernuclear program centered on magnetic analysis of the processes by which hypernuclei are formed — using magnetic spectrometers to measure the energy difference between a normal nuclear state and a hypernuclear state. But the amount of information obtained in an experiment is directly related to the energy resolution of the technique. With magnetic analysis this was only about two million electron volts, so we began looking at gamma ray transitions as another approach.

A gamma ray is a high-energy photon, a massless particle usually emitted by an ordinary nucleus during an electromagnetic transition between energy levels. But gamma rays may also be emitted by a hypernucleus, as it decays from a more excited state to a less excited state, possibly to the hypernuclear ground state. When we detect gamma emissions with sodium iodide (NaI), the energy resolution is about 100 thousand electron volts (keV), or about 20 times finer than it is with magnetic analysis.

Our NaI detectors revealed some hypernuclear secrets in 1983. We learned that the energy levels of a hypernucleus with one lambda particle are very close to the levels of the core, the basic nucleus without a lambda particle. This indicates that the interaction has a very small spin dependence (the energy of the interaction depends very little on the direction of spin of the lambda particle).

Knowing that the spin dependence is weak, we identified these states as core transitions, where the presence of the lambda particle perturbs the nuclear core, causing changes in its energy levels. We also knew that the spin of the lambda particle is one-half, so it is either oriented in the same direction as the spin of the core, or in the opposite direction. This meant that the energy levels of the core have to be split into doublets, where two hypernuclear levels exist for each core level.

Our goal during 1984 was to look at the transition between these doublet levels, to measure the spin dependence of the lambda-nucleus interaction directly. Because we needed even finer resolution than NaI could provide, we used detectors



At the hypernuclear spectrometer at the AGS, Morgan May (foreground) checks data in an experimental logbook, while Dick Sutter tests the spectrometer's main magnet.

made of germanium, which gave us a resolution of 2 keV, 50 times better than NaI.

Measuring spin dependence requires studying the various facets of spin dependence, known individually as spin-spin, tensor and spin-orbit interactions. We knew that if we could observe a spin-flip transition of a lambda particle, we would learn something about these terms in a hypernucleus.

When spin-flip occurs, if the spin of the lambda particle were oriented in the same direction as the spin of the core at the upper member (excited state) of the doublet, it would flip and be in the opposite direction to the core when the transition was completed, with the particle at the lower member of the doublet. In this case, the hypernuclear ground state. Lambda lifetime, however, is very short, so there was a possibility that the particle would not survive long enough to make the transition.

Data from our 1984 experiment, however, show that the transitions do, in fact, occur. We observed the spin-flip transition of the lambda particle, and as a result of these observations, we are beginning to understand some of the facets of spin dependence. To continue that progress, our next experiment will focus on the third aspect — the spin-orbit interaction. We will try to measure this interaction in a carbon nucleus made hypernuclear by the addition of a lambda particle.

NSF CONTRACT PHY80-22200

ANNUAL REPORT

Floyd R. Newman

LABORATORY OF NUCLEAR STUDIES

CORNELL UNIVERSITY

November 1, 1983-October 31, 1984

B. D. McDaniel, Director

SUMMARY

During the past year there have been several important accomplishments of the Laboratory. Our serious effort to improve the luminosity by the use of the 3-bunch "pretzel" mode has yielded nearly a factor of two increase in average luminosity of CESR with the promise of another comparable increase when we go to 7-bunch operation. We have made an extensive and detailed survey of the total e^+-e^- cross section between 10.8 and 11.2 GeV in the successful search for other (upsilon 5S and 6S) resonances. During the last two months of the period we have joined the search for the phantom zeta particle which was reported by the Crystal Ball group working at DESY.

The total luminosity supplied by CESR during the year amounted to 114 inverse picobarns. This was accomplished in spite of the commitment of a very large fraction of time to machine studies to develop the multi-bunch operating mode and to install a new vacuum chamber and vertex detector in CLEO. Even with the large time commitment for these purposes, the total luminosity provided during the year exceeds that of any earlier year.

The new vertex detector, which was built and installed by the Ohio State University collaborators, is operating extremely well and will greatly improve the charged particle tracking in future experiments. At the same time that these components were being installed, the CLEO group also installed new electronics for the drift chamber which permits dE/dx measurements on all layers, greatly improving the efficiency for identifying and detecting kaons.

Our superconducting rf group made major advances during this period by improved materials treatment. An accelerating field gradient of about 15 MeV per meter at S-band was obtained in a 5-cell cavity which was completely equipped with higher order mode and fundamental couplers for full operation. We believe this to be a world's record for these conditions. A test of this cavity in CESR is scheduled for the end of November.

The computer group continues to provide good service in spite of ever-increasing demands. During the past year, six 370/E emulators have been constructed. Three are currently in use and the remainder will soon be in service. Planning is proceeding for a major upgrade of the system.

CESR

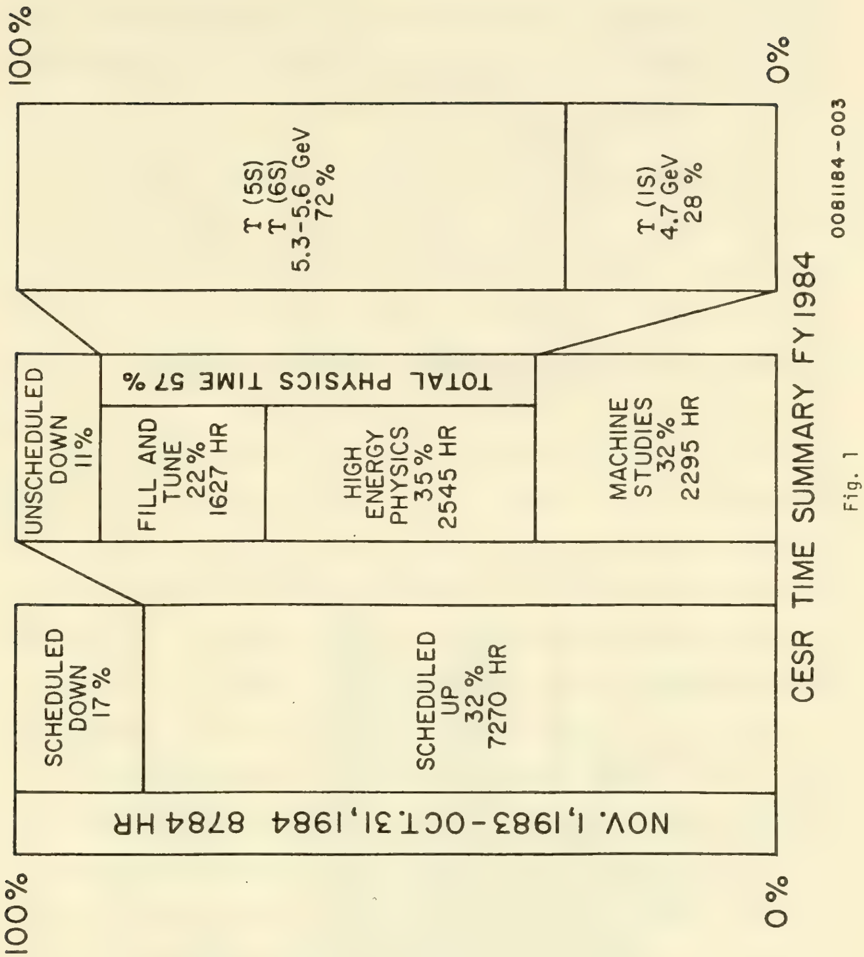
1984 was the first full year of 3 bunch per beam running for CESR. During this year performance has almost doubled compared to previous years of intensive single-bunch running. An rf cavity modified to avoid vacuum leak problems was installed and has operated for more than two-thirds of the year with no signs of trouble. The micro-beta rare earth-cobalt quadrupole properties were studied extensively and after extensive discussion and negotiation with vendors an order for material has been placed.

A breakdown of accelerator time distribution during the year is shown in Fig. 1. Unscheduled down time was a quite modest fraction of scheduled operating time; 9% for the accelerator, 2% for experiments. These figures are particularly impressive considering multi-bunch operation requires four electrostatic separators operating stably at all times while beams are colliding.

High Energy Physics

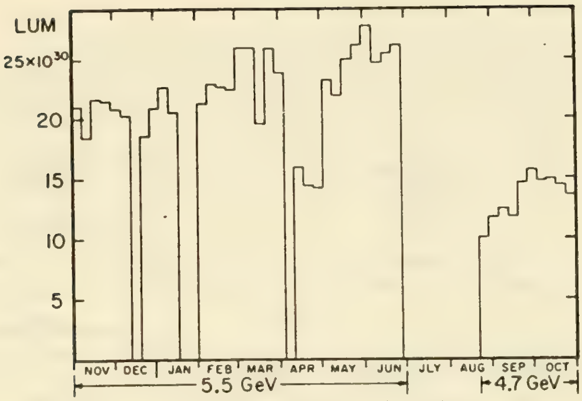
The first eight months of the year were spent scanning the energy region above the Υ(4S) resonance (10.8-11.2 GeV/c c.m.). 92 pb^{-1} were accumulated, and during this period CESR delivered as much as 1 pb^{-1}/IR in a single day. Peak luminosity hovered around 2.5×10^{31} cm^{-2} sec^{-1} for much of this period (see Fig. 2) with a maximum of 2.75×10^{31} achieved (averaged between the two IR's). For the last two months of the year 22 pb^{-1}/IR were delivered on the Υ(1S). While peak luminosity was somewhat lower due to the lower energy, multi-bunch operation produced the same factor gain (1.8) over single-bunch running as had been measured at higher energies. During this later period advances in injection resulted in repeatable filling times of 40 minutes with 30 minutes being achieved in several fills. Figure 3 shows average integrated luminosity/IR in weekly bins.

Operation with more bunches than are conventionally used to match the number of interaction regions in a storage ring has become routine at CESR and has been demonstrated to yield significant gains in luminosity. This is the first time this approach has been successfully used in a storage ring to increase luminosity. Problems in working with a vacuum chamber designed for single-bunch operation and in dealing with non-linear effects, particularly from sextupoles, have limited the gain to somewhat



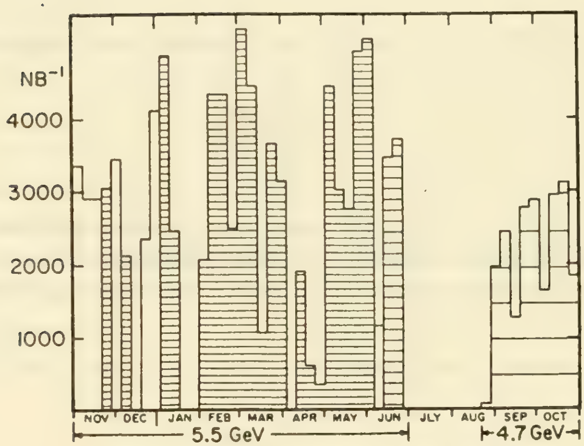
100%
0%
NOV. 1, 1983 - OCT. 31, 1984 8784 HR
SCHEDULED DOWN 17 %
SCHEDULED UP 32 % 7270 HR
UNSCHEDULED DOWN 11%
FILL AND TUNE 22 % 1627 HR
HIGH ENERGY PHYSICS 35 % 2545 HR
MACHINE STUDIES 32 % 2295 HR
TOTAL PHYSICS TIME 57 %
Υ (5S) Υ (6S) 5.3-5.6 GeV 72 %
Υ (1S) 4.7 GeV 28 %
CESR TIME SUMMARY FY1984
0081184-003

Fig. 1



PEAK LUMINOSITY IN 1984

Fig. 2.



INTEGRATED LUMINOSITY / IR / WEEK

0081184-002

Fig. 3.

less than ideal (factor of 1.8 for 3 bunches). However, we are confident that we understand these effects well enough to predict that performance with 7 bunches will reflect a factor of 3 to 3.5 gain over single-bunch operation.

In spite of the increased currents associated with multi-bunch, injection times have decreased as a result of a greatly improved injector, eliminating the need for coalescing. Further improvements in current and efficiency during the filling periods will maintain or improve the overall duty cycle even with another doubling of current with 7-bunch operation.

Machine Studies

Several machine studies periods during 1984 were devoted to multi-bunch and micro-beta developments. During December, April, and October, tests with 7 bunches per beam showed the feasibility of using 7 bunches for routine running. Luminosity of over 3×10^{31}/IR was measured, and filling times of an hour or less are consistent with performance during machine studies. Significant time was used during the year to understand the limitations resulting from aperture limits and non-linear effects.

A week during January was devoted to studying possible experimental background problems associated with the micro-beta quadrupoles. Results were encouraging. At this time we also studied the effects from the presence of a second RF cavity which will be necessary to shorten the beam bunch length during micro-beta operation. Results indicated no basic problems in beam-beam performance existed; however, appearance of a quadrupole transverse instability suggests the need of a moderately sophisticated feedback system for multiple-bunch micro-beta operation.

Several topics associated with luminosity improvement were studied during accelerator development periods. The primary instability encountered with multi-bunch operation is a transverse coupled-bunch instability possibly driven by a low frequency impedance in CESR. Theoretical estimates and measurements of likely components in the storage ring do not explain the observed beam behavior. Several days of machine study have been devoted to understanding this instability; however, we do not yet have a plausible model for this effect. Thus far we have been able to successfully operate in a 7-bunch mode using straightforward feedback and high chromaticity to provide head-tail damping.

Through comparison with measurements in CESR we are confident in using the non-linear tracking program DIMAT (from K. Brown and R. Servranckx) to model many effects in CESR, potentially saving significant machine time.

Studies of the effects of the CHESS wiggler on luminosity indicate that it may be possible to use it to control emittance. Studies of steering elements in the CHESS source region and better understanding of position monitors have reduced time and confusion involved in maintaining stable beam positions for the CHESS users.

We discovered that proper manipulation of quadrupoles could turn an annoying problem, residual vertical ripple from the vertical electrostatic separators used for injection, into an aid in multi-bunch injection. This ripple was phased to provide several millimeters of vertical separation in addition to the normal horizontal separation at the parasitic bunch crossing points in the arcs. With this new beam optics, 10 to 15 minutes have been cut off our injection time.

Better understanding of the compensation of the CLEO solenoid, aided by the DIMAT program, has resulted in reduced vertical dispersion generation and better high energy physics performance.

Accelerator Equipment

After several years of recurring problems with vacuum leaks in the CESR RF cavities, a unit was modified and it has operated since April with no signs of leaks. A second cavity has been modified and is being baked to reduce residual outgassing. The third cavity will be rebuilt after the second is shown to be a usable unit. We have supported a total circulating current in excess of 150 mA with one RF cavity, reducing some concerns about multi-bunch operation. Transmitter control circuits have been examined and optimized for better phase and amplitude control.

A new transmitter for the synchrotron RF has been commissioned. The new design permits changing klystrons without removal of the beam transport line between the synchrotron and CESR. Replacement of phase shifters and other low level equipment with state-of-the-art solid-state units is underway.

Linac reliability has been improved with the installation of solid state thyratron trigger amplifiers and new klystron monitoring equipment. New pumpout lines for the Linac vacuum system have reduced the time to recover from vacuum work.

A test beam facility was installed to allow 300 MeV positrons from the Linac to be used in measurements and calibration of CsI crystals proposed for CLEO II. This facility has operated simultaneously with colliding beam operation during periods when the Linac was not being used to fill CESR. There has been no detrimental effect on the high energy physics program.

Micro-Beta

During the first quarter, extensive tests on $SmCo_5$ magnetic material demonstrated its suitability for use in a storage ring such as CESR. These tests included: reproducibility of material and quality control capabilities of two potential manufacturers; stability of the material under stresses from elevated temperature and externally applied magnetic fields; and ability to achieve a satisfactory field distribution with our proposed quadrupole design.

In March the first of several discussions with potential manufacturers was initiated in order to produce a realistic specification. This process extended over several months since material suitable for precision quadrupoles requires careful control of many parameters during manufacture which are normally unimportant. An order was released to Vacuumschmelze in October.

A serious concern with the micro-beta lattice was the possible need for vertical trim separators since the residual orbit distortion (from the vertical separators used for injection) would double from the present ±3 mm to ±6 mm. This perturbation results in coupling and reduction of aperture. Injection improvements, careful placement of components, and lattice optimization make it likely that this expensive and manpower-intensive job can be avoided.

Since the rare earth-cobalt (REC) quadrupoles extend to within 0.6 meters of the interaction point, well within the experiment drift chamber, the accelerator physicists are working closely with CLEO physicists to avoid impossible restrictions for either group. A possible design exists, but many details remain to be resolved.

Estimates of luminosity improvement from micro-beta range from 1.5 to 2.5 times the pre-micro-beta values. The micro-beta, multi-bunch, and other operational improvements in aggregate are expected to produce luminosities in excess of 10^{32} cm^{-2} sec^{-1} and integrated luminosity of 2 to 4 pb^{-1} per day.

CLEO

Whether viewed in terms of data collection, data analysis, installation of new equipment, progress on future improvements, or publications, this has been another very successful year for the CLEO collaboration.

In the period through mid-June the CLEO group concentrated on data collection in the energy region above the Υ(4S) in a search for new hadronic structure, with a total integrated luminosity of 72 pb^{-1}. The initial analyses showed two prominent enhancements in the total cross section and in the decay branching ratio to leptons which may be interpreted as new states of heavy constituents denoted Υ(5S) and Υ(6S) (see Fig. 4). Analysis is continuing on other decay channels to learn more about the nature of these resonances.

June and July were devoted to the installation, debugging, and understanding of the high-resolution vertex detector, the thin-walled beryllium beam pipe, and the new drift chamber electronics which simultaneously measures pulse height and drift time. We also revamped the tracking trigger to be tiered (enabling us to make necessary trigger decisions in CESR 7-bunch running) and to correlate track segments in the various regions of the drift chamber when forming tracks.

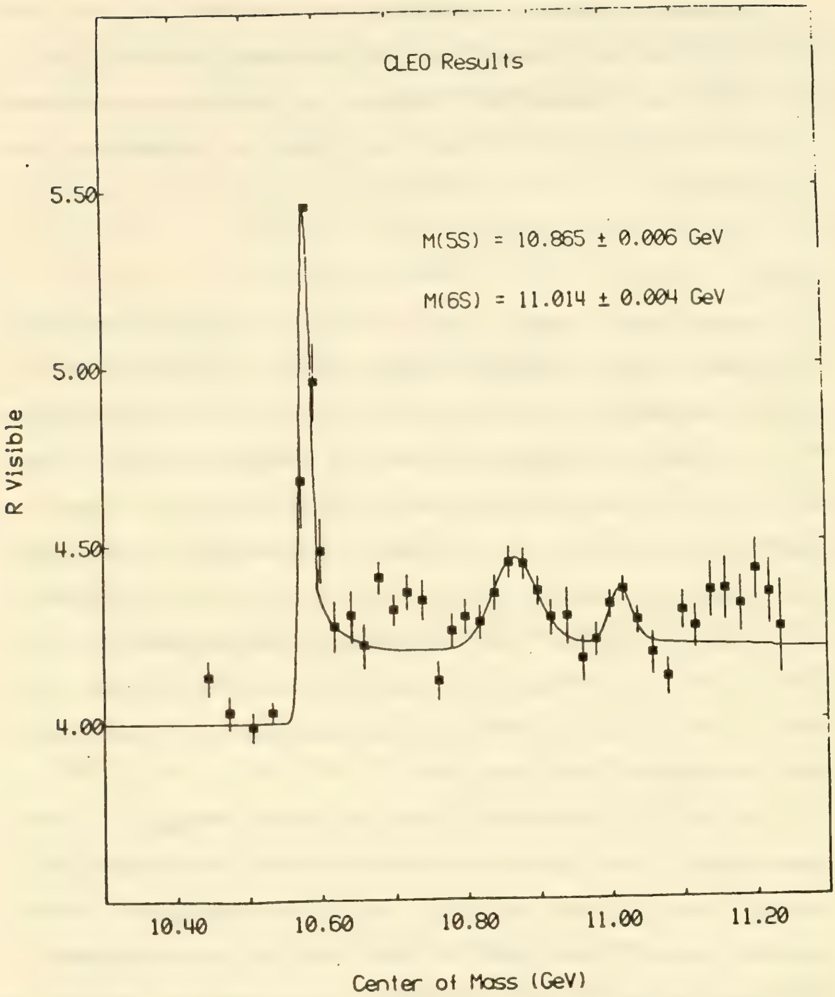

CLEO Results
M(5S) = 10.865 ± 0.006 GeV
M(6S) = 11.014 ± 0.004 GeV
5.50
5.00
4.50
4.00
R Visible
10.40
10.60
10.80
11.00
11.20
Center of Mass (GeV)
2170784-015

Fig. 4

We are completing our first data run with these improvements, having collected 15 pb^{-1} at the Υ energy and now running in the continuum below the resonance. For this period we installed a lead cylinder between the vertex chamber and the main drift chamber of thickness 10% of a radiation length in order to make CLEO a high-resolution photon detector. Among the goals of this effort are (i) the verification/denial of the zeta observed at DESY, (ii) a detailed measurement of the branching fractions of Υ to Υgg and $\tau\tau$, and (iii) a limit on heavy axion production.

The new elements work very well indeed:

(a) with the correlated tracking trigger CLEO finally has a high-efficiency two-track trigger with an acceptable rate.

(b) the vertex detector participates in the trigger and has a spatial resolution of 90μ for Bhabhas and 110μ for hadrons. It is very efficient and provides an excellent veto in our effort to find photons which convert in the lead.

(c) the new drift chamber electronics has the anticipated dE/dx resolution (σ/E = 87% per layer) and e/μ separation (see Fig. 5); the new electronics still gives good spatial resolution, namely for 165μ hadrons.

<u>Progress on the New Drift Chamber</u>

During the past year the endplates for the chamber have been drilled and delivered to a newly constructed clean room. New methods for stringing and holding wires have been perfected and the target date for stringing completion is June, 1985. Hybrid preamp design has also been finished and prototypes have been ordered for delivery by January, 1985. These and other electronic components (HV, pulse height, timing, etc.) should be

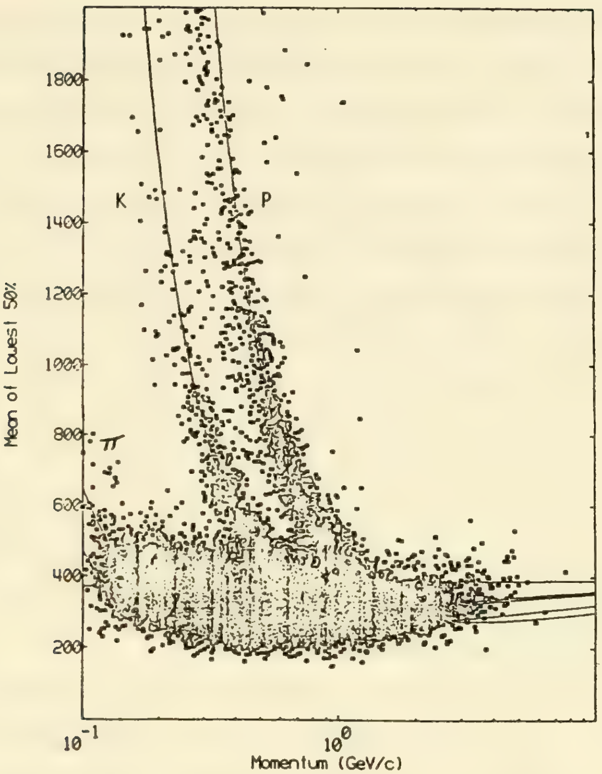


Fig. 5. Plot of dE/dx of the drift chamber vs. momentum. The ordinate is the mean of the lowest 50 percent of the pulse heights in the 17 layers of wires. The separation of the pi's, K's and P's is clearly shown.

completed by June, 1985. We have also decided on the scheme of the track segment trigger and have started to design it.

We presently plan to install the completed chamber starting September 1985 to coincide with the CESR micro-beta installation. It will take roughly three months to remove the old chamber and electronics, install the new chamber and its electronics, and test the system.

CLEO II Progress

The current design of the CLEO II electromagnetic calorimeter calls for 8000 CsI crystals, each 16 radiation lengths long with a total volume of eight million cubic centimeters. We have begun acquiring and testing these crystals. We have used radioactive sources to determine the output light quality. In tests using the 180 MeV positron beam of the Linac, we have achieved an rms crystal resolution of 4%. We plan to construct an end cap calorimeter using 500 such crystals and install it in CLEO at the same time as the new drift chamber.

The other aspects of CLEO II are progressing as well. Two companies have submitted detailed design studies for the new superconducting coil; investigations are underway to acquire the necessary iron for the flux return and hadron shield; tests are starting on both the electronics and the counter designs for the muon and time-of-flight systems.

Conferences with CLEO Speakers

Electroweak Interactions, Moriond, Les Arcs, France
New Particles, Moriond, Les Arcs, France
Flavor Mixing Conference, Erice, Italy
Instrumentations Conference, Novosibirsk, USSR
Vanderbilt Conference, Nashville, TN, USA
American Physical Society meeting, Washington, DC
Weak Interactions Conference, Madison, WI, USA
Multiparticle Dynamics, Lund, Sweden

SURA Conference, Virginia, USA
Trieste Conference, Trieste, Italy
International HEP-XXII, Leipzig, GDR
SLAC Summer Institute, Stanford, CA, USA
Collisions Workshop, Hamburg, FDR
DESY Workshop, Hamburg, FDR
IEEE Conference, Orlando, FL, USA
SE American Physical Society meeting, Memphis, TN, USA
Division of Particles and Fields, Santa Fe, NM, USA

Publications this Fiscal Year

Total Cross Section for e^+e^- Annihilation into Hadron Final States in the Υ Energy Region
(with the CLEO collaboration, R. Giles et al.),
Phys. Rev. D 29, 1285 (1984).

Observation of Radiative Decays of the Υ(2S)
(with the CLEO collaboration, P. Haas et al.),
Phys. Rev. Lett. 52, 799 (1984).

A Search for the ξ(2.2) in the Upsilon Region
(with the CLEO collaboration, S. Behrends et al.),
Physics Letters 137B, 277 (1984).

Limit on the b → u Coupling from Semileptonic B Decay
(with the CLEO collaboration, A. Chen et al.),
Phys. Rev. Lett. 53, 1084 (1984).

Hyperon Production in e^+e^- Interactions in the Upsilon Region
(with the CLEO collaboration, M. S. Alam et al.),
Phys. Rev. Lett. 53, 24 (1984).

Upper Limit on Flavor-Changing Neutral Current Decays of the b Quark
(with the CLEO collaboration, P. Avery et al.),
Phys. Rev. Lett. 53, 1309 (1984).

High Statistics Study of Υ(2S) to p^+p^- Υ(1S)
(with the CLEO collaboration, D. Besson et al.),
Phys. Rev. D 30, 1433 (1984).

Leptonic Branching Ratio of the Υ(2S)
(with the CLEO collaboration, P. Haas et al.),
Phys. Rev. D 30, 1996 (1984).

SUPERCONDUCTING RF PROGRAM

The principal activity of the superconducting rf program has been development and construction of four five-cell 1500 MHz "elliptical" accelerating cavities for storage ring service. These cavities are complete with integral waveguides for coupling high power into the cavity and damping beam-induced higher order modes which would otherwise destroy the beam. A substantial fraction of the program effort was devoted to determining the higher order mode damping requirements and developing couplers which provided this damping without degrading the performance of the cavities. Three such cavities have been completed and have achieved accelerating gradients of 8.9, 8.0, and 15.3 MeV/m at Q's of 7×10^9, 3.5×10^9, and 2×10^9, respectively; these gradients are significantly higher than those previously achieved in multi-cell storage ring cavities with all coupling devices in place, at Cornell or elsewhere. Two of these cavities have been chemically processed, installed in the "horizontal" cryostat for installation in CESR, and tested without beam using a solid-state rf amplifier. In the test in the horizontal cryostat, both cavities exceeded 3 MeV/m (limited by available rf power because of the strong input coupling), exhibited Q values at this field of 3.1×10^9 and 2.3×10^9, respectively, and could be tuned to the correct frequency using stepping motors in the liquid helium. The static heat load of the cryostat was measured to be less than 7 watts. This system, in its current state, will be installed in CESR for a test run within the coming month.

Due to the high fields being reached in these cavities, it has become impractical to protect personnel from x-rays by wrapping cryostats in

lead. Two shielded caves, with interlocked monitors, are being constructed for future high-field testing. Other facilities improvements have included a new computer numerically controlled mill, which is now in regular use for making precision parts and complex shapes, and a clean enclosure around the electron beam welder, which is expected to prevent dust being included in welds, a problem in the past, from being a problem in the future.

Bunched-beam instabilities involving internal distortion of the bunches due to high-Q resonators have frequently been predicted but have never been observed in electron storage rings with suitably adjusted lattice parameters. Particle tracking simulations show that the absence of such instabilities in the case of transverse motion is due to the curvature of the rf restoring force, and the Landau damping which this curvature provides. This is a useful result, since feedback can be applied to rigid bunch motion (for which case the Landau damping does not apply), but it is difficult to apply feedback to internal bunch motion.

Work to improve the thermal conductivity of niobium (and hence its stability against quenches induced by localized hot spots) has continued. Collaboration with other laboratories and companies has led to the production by Ames Laboratory, Fansteel, and Heraeus of high purity niobium with 3 to 5 times the thermal conductivity of standard reactor grade niobium. Treatment of standard reactor grade niobium with yttrium has also yielded thermal conductivities 3 times those of reactor grade niobium. A fourth 5-cell cavity made of the yttrium-treated Heraeus material is under construction (the cavities being used for our beam test in CESR have 3 times the thermal conductivity of reactor grade niobium).

Initial studies directed toward further improvement in performance of superconducting cavities and toward their application to colliding linear accelerators have included evaluation of apparatus available for studying surface properties of large samples, and calculations of cavity designs suitable for producing high magnetic and electric fields on demountable flat plates and for producing high electric fields over large areas. Thermometry improvements including thermometers with 10 microdegrees Kelvin sensitivity, vacuum-insulated thermometers for use in superfluid helium, and sensitive thin-film thermometers using a mixture of aluminum and silicon monoxide have been made.

Work has continued on studies of benefits obtained by dissolving a surface oxide of niobium into a previously deoxidized bulk. A factor of two reduction in rf power dissipation has been demonstrated using this method.

Work has also continued on calculations of particle trajectories through groups of successively rotated laser-powered grating accelerators, and of the effects of fields induced by the bunch on the dynamics of the particles in the bunch.

COMPUTER FACILITY

The DECsystem-1099 ("KL") computer continues to be saturated. For the more stable production analysis code for CLEO we have built six 370/E emulators. Our intent is to have five running with the sixth as a spare. Currently three are working and three are in the final stages of debugging. They are attached via ETHERNET to the VAX/780 which serves as a host and I/O server for them. Each 370/E has raw compute speed of approximately two times that of a VAX/780 or two-thirds that of the dual

processor KL computer. We expect to have the CLEO "compress" code running in the emulators very soon; this will hopefully relieve some of the immediate burden on the KL. We are starting to investigate the idea of "farms" of small but fast micro processors such as the MicroVAX to be used in the same role as the 370/E's. These would have the advantage of being much easier to program since the programs would be completely compatible with our larger VAX systems.

In the previous year we purchased two VAX/750 computers to replace the DECsytem-1070 ("KI") computer which had been used for CLEO on-line data analysis and CESR control system. In January the CESR control system was converted to the VAX (CLEO on-line data analysis had been converted earlier) and the KI was finally turned off forever, after ten years of service. Two more VAX/750 computers were purchased during this year, nominally to replace the CLEO data acquisition PDP-11/34 and provide backup and development capability for CLEO and CESR. We have not yet replaced the CLEO PDP-11/34, and it looks as if improvements to our software may make it possible to perform the data acquisition directly to the on-line data analysis VAX/750 and simply eliminate the PDP-11/34.

As CESR luminosity increases, we may need two VAX/750's for on-line data acquisition, but, until then, the second CESR VAX/750 (and most of the backup and development VAX/750) will be used for accelerator theory calculations. The VAX/780 which was originally purchased primarily for accelerator theory will now be used primarily for word processing and CLEO software development. This reassignment of VAX functions seems to be better for everyone and allows us to prepare more effectively for future computer options.

None of the VAX/750 computers were purchased with high density 6250 bpi magnetic tape drives since they were not available from DEC at the time. Because too many tapes are required at lower densities, 6250 bpi is required for backing up the disks. We have now purchased four CDC Keystone streaming tape drives with Emulex controllers and expect to have them installed early in the next fiscal year.

We have long recognized the need for substantially more general purpose computing capacity than is available with our current configuration. For the last two years we have felt there were two realistic approaches to solving these needs. One is to assemble a "cluster" of high speed VAX systems sharing a common file system and the other is to obtain a single large IBM (or IBM compatible) mainframe computer. The major advantage of the former approach is compatibility with our current hardware/software and flexible expandability. The major advantage of the latter approach is that IBM, and its plug compatible competitors, will probably always have single cpu's that are more powerful than the cpu's DEC will supply to run in clusters. This means that the number of cpu's to meet the total need can be smaller and utilization can be more efficient. It remains to be seen which approach is more cost effective.

We have issued a letter of purchase for the recently announced DEC VAX/8600 system to hold an early delivery slot. In early December we will be assembling an advisory panel of external experts to help us decide between these or perhaps other directions. Pending the report of the advisory panel we can decide to accept delivery of the VAX/8600 or cancel with no penalty.

Ethernet, with DECnet software, provides the network environment for users on our VAX systems. We have implemented an experimental protocol, called "LAT", which runs on PDP-11/34 computers and we are using this as a terminal server so that any terminal attached to the LAT box can access any of the VAXes. An important addition to this was accomplished this summer when we were able to extend the Ethernet link to Newman Laboratory; with a LAT box at Newman, terminal users there can easily access any of the VAXes at Wilson Lab.

After extensive investigation we have purchased the MASS-11 software package for word processing at the Laboratory. This package runs on VAXes and DEC Rainbow personal computers and provides "what-you-see-is-what-you-get" editing of documents with equations and Greek letters. It is now being used extensively for document preparation by physicists and secretaries and has been generally successful. To overcome the bottle-neck of typing the output on relatively slow Diablo 630 ECS daisy wheel printers, we plan to acquire a laser printer which will also be able to do graphics output. To provide terminals which are capable of displaying the Greek letters and mathematical symbols we have started purchasing DEC VT220 terminals which have downline loadable font capability.

The PDP-11/34 computer that was used for CLEO hardware and software development has been incorporated into the crystal testing facility for the CLEO II calorimeter. This facility uses the new Linac test beam and has been successfully used in evaluating the cesium iodide crystals that have been delivered so far.

SSC ACTIVITIES

During the past year, several individuals in the Laboratory have been involved in activities connected with the national Superconducting Super Collider program. In July, 1983, the High Energy Physics Advisory Panel of the Department of Energy named as the highest priority of the high energy physics community research and development leading to the construction of a proton-proton colliding beam facility at an energy of 10 to 20 TeV per beam.

Prof. Maury Tigner has played a major role in this activity. In the period from January to May, he led an ad hoc Reference Designs Group (150 participants) to develop an improved cost estimate for such a facility. This was a very successful effort which eventually led the Department of Energy to commit $20 M of funds for R/D for FY 1985. These funds have been assigned to the Universities Research Association to act as contractor. A sub-board called the SSC Board of Overseers has been established to supervise these activities. Prof. McDaniel has been appointed Chairman of this Board. He has been relieved of his teaching obligation to the Department of Physics to take up this activity. One-quarter of his salary is now paid by URA, one-quarter by the Department of Physics, and one-half by the NSF CESR contract.

To carry on the Research and Development activity a Central Design Group has been established at the Lawrence Berkeley Laboratory under the Direction of Prof. Tigner. Prof. Tigner has been granted a three-year leave of absence from Cornell University in order to assume the direction of this activity.

A few other members of the Laboratory have also been involved in occasional SSC-associated activities. Professors Gilchriese and Hartill have been involved in early discussions of detector planning while Prof. Robert Siemann and Dr. Nari Mistry have had relatively minor involvement in serving on SSC committees.

Financial Statement
(Annual)

The commitments for the period are $11,826,137 bringing the committed to date to $36,115,418. The free balance is $768,176.

Period Ending 10/31/84

ANNUAL REPORT
NSF PHY 80-22200

	Budget	Committed to Date	Committed this period	Free Balance
I. EQUIPMENT				
CESR Operations	$ 2,794,400	$ 2,633,798	$ 1,250,710	$ 160,602
Purchased Equipment	991,000	978,399	235,607	12,601
*Fabricated Equipment	1,803,400	1,655,399	1,015,103	148,001
CLEO Equipment	$ 2,536,037	$ 2,921,327	$ 2,260,983	$ (385,290)
Purchased Equipment	1,718,824	1,619,415	1,190,859	99,409
*Fabricated Equipment	817,213	1,301,912	1,070,124	(484,699)
COMPUTER	$ 2,091,500	$ 1,329,911	$ 345,585	$ 761,589
Purchased Equipment	1,769,000	1,097,012	263,877	671,988
*Fabricated Equipment	322,500	232,899	81,708	89,601
SUPERCONDUCTING RF	$ 2,533,700	$ 2,216,863	$ 889,889	$ 316,837
Purchased Equipment	1,137,000	906,077	269,691	230,923
*Fabricated Equipment	1,396,700	1,310,786	620,198	85,914
TOTAL EQUIPMENT	$ 9,955,637	$ 9,101,899	$ 4,747,167	$ 853,738
*Includes salaries with associated fringes and Supplies and Materials				
I. OPERATIONS				
Salaries & Fringes - CESR	$ 4,593,700	$ 4,600,107	$ 1,179,663	$ (6,407)
Salaries & Fringes - Admin.	$ 973,100	$ 1,017,517	$ 296,807	$ (44,417)
Materials & Supplies	$ 1,711,000	$ 1,765,307	$ 464,785	$ (54,307)
Electric Power	$ 3,573,500	$ 3,500,037	$ 827,040	$ 73,463
Other Expenses	$ 1,886,100	$ 1,830,650	$ 511,707	$ 55,450
Telephone	87,000	93,167	29,067	(6,167)
Freight	31,100	35,546	11,672	(4,446)
Domestic Travel	204,800	224,167	81, 522	(19,367)
Foreign Travel	45,100	26,636	3,807	18,464
Assembly & Storage	62,200	47,775	12,302	14,425
Computer Maint. & Repair	953,500	910,796	228,368	42,704
Consultants	36,000	18,075	2,600	17,925
Publications	10,100	10,374	2,235	(274)
Miscellaneous	456,300	464,114	140,134	(7,814)
Indirect Cost	$ 3,816,300	$ 3,892,942	$ 1,280,111	$ (76,642)
TOTAL OPERATIONS	$16,553,700	$ 16,606,560	$ 4,560,113	$ (52,860)

	Budget	Committed to Date	Committed this period	Free Balance
III. RESEARCH				
Salaries & Fringes - CLEO Research	$ 1,934,300	$ 1,978,192	$ 526,533	$ (43,892)
Salaries & Fringes - CLEO Support	$ 1,505,200	$ 1,473,060	$ 341,755	$ 32,140
Salaries & Fringes - Super RF	$ 1,369,900	$ 1,356,114	$ 191,509	$ 13,786
Materials & Supplies - CLEO	$ 974,000	$ 961,939	$ 245,658	$ 12,061
Materials & Supplies - SRF	$ 1,082,219	$ 1,045,265	$ 178,591	$ 36,954
Materials & Supplies - Computer	$ 131,500	$ 163,306	$ 54,919	$ (31,806)
Other Expenses	$ 140,600	$ 174,768	$ 77,079	$ (34,168)
Domestic Travel	92,500	106,906	39,136	(14,406)
Foreign Travel	41,500	61,131	35,287	(19,631)
Publications	6,600	6,731	2,656	(131)
Indirect Cost	$ 3,236,538	$ 3,254,315	$ 902,813	$ (17,777)
TOTAL RESEARCH	$10,374,257	$ 10,406,959	$ 2,518,857	$ (32,702)
G R A N D T O T A L	$36,883,594	$ 36,115,418	$11,826,137	$ 768,176

V. SALARY & SALARY RELATED BY POSITION

	Operations	CESR Capital	Admin.	Comp. Capital	Research	Res. Support	CLEO Capital	Super RF	SRF Capital	Total
ACULTY	354,640	--	--	--	229,236	75,164	--	13,790	--	672,830
R. Res. Assoc.	39,967	23,072	--	7,917	352,178	15,410	82,276	143,602	102,215	766,637
ES. Assoc.	252,281	86,864	--	2,690	693,253	91,719	137,706	249,532	305,618	1,819,663
RAD. Res. Asst.	209,772	--	--	--	400,137	--	--	91,329	--	701,238
ECHNICAL	2,859,543	610,455	--	125,342	--	1,006,323	246,522	599,032	407,144	5,854,361
DMINISTRATIVE	--	--	802,069	--	--	--	--	--	--	802,069
OTAL SALARY	3,716,203	720,391	802,069	135,949	1,674,804	1,188,616	466,504	1,097,285	814,977	10,616,798
RINGE BENEFITS	883,904	201,093	215,448	37,912	303,388	284,444	129,808	258,829	227,560	2,542,386
NDIRECT COSTS	2,549,997	--	562,161	--	1,086,163	831,374	--	767,049	--	5,796,744
OTAL	7,150,104	921,484	1,579,678	173,861	3,064,355	2,304,434	596,312	2,123,163	1,042,537	18,955,928